EMFAC2017 Volume III - Technical Documentation

V1.0.2

July 20, 2018

Mobile Source Analysis Branch

Air Quality Planning & Science Division

CONTENTS

LIST OF FIGURES AND TABLES

1. EXECUTIVE SUMMARY

1.1. OVERVIEW

This Technical Document provides technical details on the changes and updates in EMFAC2017 and also provides information regarding the differences between EMFAC2017 and the prior version of the model, EMFAC2014. For more information on how to use EMFAC2017, including how to install the model and how to navigate through the EMFAC2017 user interface, please refer to the EMFAC2017 User's Guide[1].

Some legacy components, methodologies, data, and logic are carried over into EMFAC2017 from prior versions of EMFAC and are not covered within this document.

1.2. STRUCTURE OF THIS DOCUMENT

The structure of the Technical Document is laid out as follows:

- In this *Executive Summary* chapter (Chapter 1), readers will find high-level information on the new features/characteristics of EMFAC2017 and major differences between the prior version of the model, EMFAC2014, and EMFAC2017.
- An *Introduction* (Chapter 2) provides a more detailed summary of what's new in EMFAC2017 along with specific chapter references where the reader can find more details. It also provides some very basic information on the web-based inventory data tool.
- *Chapter 3* provide details of new modules implemented in EMFAC2017 model such as: Greenhouse Gas, Transit, and Natural Gas modules.
- *Chapter 4* provides details on the model's Methodology Updates, with extensive information on how EMFAC2017 calculates vehicle emission rates and activities.
- *Chapter 5* presents impact of updates to emission rates and vehicle activities to criteria emissions and fuel consumptions from EMFAC model. It shows comparison of emission estimates by EMFAC2014 to those from EMFAC2017.

[1] See https://www.arb.ca.gov/msei/downloads/emfac2017_users_guide_final.pdf

1.3. NEW FEATURES

The EMFAC2017 model provides additional capability to come up with GHG emission estimates. A GHG module consistent with CARB's official methodology is developed and included in the EMFAC2017. The GHG module can generate emissions of the following three climate pollutants: CO_2, CH_4, and N_2O, as well as their CO_2 equivalents (CO_2e) based on GWP values from IPCC's Fourth Assessment Report (AR4).

Additionally, in EMFAC2017, staff have introduced a new module to improve the characterization of activity and emissions from transit buses. Transit buses, namely, the "urban buses" category in EMFAC, covers a mix of vehicles that are diverse in body types, fuel types, and weight class. Previous versions of EMFAC model only differentiate transit buses by fuel type. The new module differentiates transit buses by body type and weight class in addition to fuel type, and associates each sub-category with appropriate useful life and emission rates. We also updated transit bus emission rates by incorporating the latest testing data on diesel and compressed natural gas (CNG) buses.

Unlike the EMFAC2014 model and prior versions that only provided emissions of gasoline and diesel vehicles, EMFAC2017 allow the users to estimate emissions of natural gas powered vehicles in addition to gasoline and diesel. This new module estimates the fraction of natural gas vehicles among heavy duty truck population at the air district level and applies it to diesel heavy duty truck outputs to produce natural gas heavy duty (NGHD) vehicle emissions and activity outputs. Although NGHD vehicles have different emission characteristics compared to those of diesel vehicles, the current module treat emissions from NGHD vehicles the same as diesel heavy duty trucks. It needs to be noted that this module is still an experimental feature of the EMFAC model which only works under "emission" mode. Upon availability of appropriate emission test data, this natural gas module will be improved in future versions of the EMFAC model.

1.4. OVERVIEW OF CHANGES ASSOCIATED WITH THIS UPDATE

1.4.1. FLEET CHARACTERIZATION

Multiple Years of Updated DMV Data. While vehicle population in EMFAC2014 was based on 2000 – 2012 vehicle registration data from California Department of Motor Vehicles (DMV), EMFAC2017 uses DMV populations for years 2000 through 2016. The additional 4 years of DMV registration data (2013 – 2016) reflects the most recent changes to California motor vehicle fleet characteristics.

International Registration Plan (IRP) Data. IRP Clearinghouse data is another primary source to estimate heavy duty vehicle population. Vehicles already registered in California can be identified as interstate trucks (CA IRP fleet) or buses (motor coach fleet). And for out-of-state vehicles in states and provinces that report to the IRP Clearinghouse, updates can be made using vehicle characteristics for fleets with travel to California. As part of EMFAC2017, most recent IRP data were used.

TRUCRS[2] data for diesel Truck and Bus Rule. Data was extracted from the TRUCRS database to update the heavy-duty inventory as needed for fleets utilizing flexible compliance options to meet Truck and Bus Rule requirements.

Vehicle Data from Major Ports. For EMFAC2017, the Port of Los Angeles/Long Beach and the Port of Oakland provided lists of VINs for vehicles that actually visited the ports to directly identify these vehicles in the DMV vehicle registration database as port trucks.

Data from California Highway Patrol (CHP) School Bus Inspections[3]. As public school buses have exempt plates and do not need to register every year with DMV, it is difficult to identify from DMV vehicle registration data the school buses that are in operation. To better identify these vehicles in California, school bus data from the CHP were used. CHP now provides data on School Buses that receive safety inspections, which are required by law.

National Transit Database (NTD) data. Similar to school buses, most of the urban transit buses also have exempt plates. Although some urban buses may have valid registrations, some might not be actively operating, and identifying these urban buses is not feasible from DMV data. The National Transit Database[4] was used to characterize the transit fleet for EMFAC2017 in the newly developed transit bus module.

1.4.2. IN-USE EMISSIONS

1.4.2.1. LIGHT DUTY VEHICLES

For Light Duty Vehicles, the EMFAC2014 and prior versions were using emission factors that were based on testing done in the 1990's. With the implementation of new regulations such as LEVII and LEVIII, engine and emission control technologies use of alternative fuels are rapidly evolving. As part of EMFAC2017, staff updated both running and start exhaust emission rates using new Federal Test Procedure (FTP) data from the US EPA's In-Use Vehicle Program (IUVP) and emission test data from the CARB's Vehicle Surveillance Program (VSP). These updates have resulted in higher start emissions and lower running exhaust emissions for most of the light duty vehicles in today's fleet. Due to lack of data on evaporative emissions, EMFAC2014 evaporative emissions are used for EMFAC2017.

Smog Check inspection and maintenance (I/M) benefits were estimated in the previous versions of the EMFAC model (i.e., EMFAC2000 – 2014) based on data collected decades ago from vehicles that were subject to (with) Smog Check and vehicles that were not subject to (without) Smog Check. Since today's entire California vehicle fleet has been subject to Smog Check I/M for decades, there are currently no vehicle emission rate data available to represent emission levels for vehicles that are not subject to it. Because of this, for EMFAC2017 model, CARB and California Bureau of Automotive Repair (BAR) have agreed that the California Smog Check I/M

[2] https://www.arb.ca.gov/msprog/onrdiesel/reportinginfo.htm
[3] https://www.chp.ca.gov/Programs-Services/Programs/School-Bus-Program
[4] https://www.transit.dot.gov/ntd

Benefits module within EMFAC (CALIMFAC) will be discontinued. As such, EMFAC2017 will no longer have the capability to estimate benefits of the smog check program.

In addition to update to criteria pollutants, EMFAC2017 model also incorporates updated CO2 emission rates for light duty vehicles using national fuel efficiency data from www.fueleconomy.gov, the official U.S. government source for fuel efficiency information.

1.4.2.2. HEAVY DUTY VEHICLES

For medium heavy-duty (MHD) and heavy heavy-duty (HHD) diesel trucks, the running and idle ERs for EMFAC2014 were based on the test data from the Coordinating Research Council (CRC) E-55/59 study and test data from CARB and South Coast Air Quality Management District (SCAQMD). No test data were available for MHD and HHD gasoline trucks and their ERs in EMFAC were derived from those for LHD gasoline trucks. For transit buses, available data were mostly for older model year diesel buses and only a small fraction were for late model natural gas buses. As a result, the ERs of transit buses in EMFAC2014 were estimated by using these data, with ratios of heavy-duty truck emission rates used as scaling factors for several model years. Very little emissions test data of trash trucks existed previously and some data were collected by SCAQMD, which recently provided the basis for the ERs of these trucks in EMFAC2014.

For EMFAC2017, staff have utilized data from:

- *EMA-UC Riverside* testing of five late model trucks and related CARB confirmatory testing of three of the five trucks. This project provided data for updating HHD diesel truck base emission rates (BER) and speed correction factors (SCF).
- *CARB's Truck and Bus Surveillance Program (TBSP)* – designed to collect in-use emissions data for improving the emissions inventory of heavy duty vehicles, among other objectives. To date, a total of 20 heavy heavy-duty trucks (Class 8) have been tested, and test data are summarized in Appendix 6.5. This dataset was used for updating base emission rates (BERs) and Speed Correction Factors (SCF) of trucks and buses powered by diesel and natural gas.
- *CARB PEMS testing* of late model HHD diesel truck (Project 2R1406) to study low temperature SCR performance and collect data on truck emissions during extended idle and start phase.
- *TTI idle testing data* – As part of a truck emissions study project, TTI tested 15 trucks for their idle emissions. The idle testing was conducted inside a test chamber under controlled conditions, with temperature set at 100 °F for hot tests and at 30 °F for cold tests to simulate summer and winter weather conditions.
- *Integrated Bus Information System (IBIS) of West Virginia University (WVU)* which includes chassis dynamometer testing results of transit buses tested over several common test cycles.

- *CARB's Transit Bus Testing* – Chassis Dynamometer testing of two diesel buses of 2011 model year and three CNG buses of 2011 and 2012 model years for Valley Transit Agency (VTA). The emissions results are based on the OCBC test cycle. In addition, CARB recently also tested two 2008 model year CNG buses on dynamometer over the OCBC cycle as part of laboratory-field testing study of transit buses.

- *Altoona Bus Data* – The Altoona center tests transit buses from manufacturers and provide an unbiased and accurate comparison of bus models using an established set of safety and emissions test procedures. The emissions testing is performed on all buses so that emission levels of different buses can be compared and can be used by transit operators for purchase decisions. The Altoona data includes test results of some of the newest model year buses.

Using these emission datasets, BERs, SCF, Starts and Idling emission factors for medium heavy-duty and heavy heavy-duty vehicles (above 14,000 lbs. GVWR) were updated in EMFAC2017. Compared to EMFAC2014, NOx and PM emission factors for heavy duty diesel trucks and buses are higher in EMFAC2017. In terms of emission deterioration, for EMFAC2017, staff has reviewed the information and data available regarding the in-use performance of SCR and DPF on a fleet-wide basis and made revisions when deemed necessary. As a result of these updates, staff made an adjustment to the frequency of all NOx and PM related TM&M categories for 2010+ MY engines. Staff also updated the emission rate increase associated with PM related TM&M.

1.4.3. ACTIVITY

Activity profile refers to the collection of vehicle activity characteristics that influence vehicle emissions, including mileage accrual rates, speed profile, starts per day, soak time distribution, VMT hourly distribution, start hourly distribution, engine on time distribution and annual mileage accrual rate. EMFAC model developed default activity profiles for light-duty vehicles (LDVs) and Heavy duty vehicles (HDVs) to support emission inventory estimation. EMFAC2017 implemented major updates on activity profile for both LDVs and HDs using the latest vehicle data collected recently. These datasets include:

Bureau of Automotive Repair (BAR) Smog Check Data were used to derive regional mileage accrual rates by vehicle age and class for LD vehicles using similar methods that have been employed since EMFAC2007.

The 2010-2012 California Household Travel Survey which collected data from over 42 thousand of households between January 2012 and January 2013. For the purpose of EMFAC update, the in-vehicle GPS and OBD data were used as the primary source to create the number of the starts, soak time distribution, and engine run time distribution. These data included 1,440 households with both in-vehicle GPS devices and 422 households with in-vehicle GPS device only. Each household were provided with a maximum of three GPS or OBD devices to instrument their vehicles. In total, trip data are available from 2,715 vehicles with both GPS and

OBD, and from 776 vehicles with GPS only. This dataset was used to update activity profiles associated with light duty vehicles.

Activity data from UCR CE-CERT study which collected vehicle and engine activity data from 90 heavy-duty vehicles that make up 19 different groups defined by vocation, GVWR and geographic region[5]. The study targeted 2010 or newer heavy duty vehicles that were mostly equipped with SCR technology. For each truck, data were collected using GPS and ECU data loggers at 1Hz resolution for a period of at least one month. Using this dataset, speed profiles, soak time distribution, number of starts per day, and idling hours associated with heavy duty vehicles were updated.

It needs to be noted that for conformity and State Implementation Plan purposes, user may use local activity profiles developed by transportation planning agencies and run the EMFAC model in the Custom Activity Emissions Mode to develop regional emission inventories for planning.

1.4.4. SOCIO-ECONOMETRIC FORECASTING

As described in EMFAC2014 technical support documentation[6], EMFAC2014 uses socio-econometric regression model forecasting methods to predict new vehicle sales and VMT growth trends. These models connect the activity estimates of EMFAC to state and national economic indicators, fuel prices, regional human populations, and regional vehicle ownership characteristics. For EMFAC2017, staff updated the socio-economic data in EMFAC model using the latest available data from UCLA Anderson Forecast (UCLA), California Department of Finance (DOF), California Board of Equalization (BOE), California Energy Commission (CEC), U.S. DOE Energy Information Administration (EIA), and U.S. Bureau of Economic Analysis (BEA).

1.4.5. REGULATIONS AND POLICIES

EMFAC2017 also reflects state and federal laws, regulations, and legislative actions that were adopted as of December 2017. The regulations and standards were aimed at lowering fleet average emission rates and were designed to improve air quality and reduce greenhouse gas (GHG) emissions. The regulations and policies reflected in EMFAC2017 include:

Phase 2 GHG standards – On August 16, 2016, the U.S. EPA and NHTSA released a pre-publication version of the Phase 2 standards. The final version of the Phase 2 rule was published in October 25, 2016. The Phase 2 standards are the second phase of federal heavy–duty GHG standards and build upon the Phase 1 standards. The regulation imposes new requirements for newly manufactured compression and spark ignited engines in Class 2b through Class 8 vehicles. Phase 2 requirements begin with model year 2018 for trailers and model year 2021 for engines and vehicles, and phase–in through 2027 model year.

---

[5] Boriboonsomsin, K., Johnson, K., Scora, G., Sandez, D., Vu, A., Durbin, T., & Jiang, Y. (2017) Collection of Activity Data from On-Road Heavy-Duty Diesel Vehicles. Available at https://www.arb.ca.gov/research/apr/past/13-301.pdf

[6] https://www.arb.ca.gov/msei/downloads/emfac2014/emfac2014-vol3-technical-documentation-052015.pdf

Senate Bill 1 - SB 1, The Road Repair and Accountability Act of 2017, is intended to address the funding deficit for transportation infrastructure, and the backlog of California transportation system maintenance and rehabilitation projects. Besides addressing the funding deficit, the bill requires the Department of Motor Vehicles (DMV), starting January 1, 2020, to verify that a medium-duty or heavy-duty vehicle is compliant with or exempt from CARB’s Truck and Bus Regulation (Section 2025 of Title 13 of the California Code of Regulations) before allowing registration. Following this bill, the compliance assumptions in EMFAC2017 model were updated to ensure that full compliance will be achieved by January 1, 2023.

Besides the above mentioned laws and regulations, EMFAC2017 also incorporates updates to assumptions on Advanced Clean Cars (ACC) regulation based on the 2017 Midterm review of ACC. These updates include:

- Updates to Zero Emission Vehicle sales forecast
- Updated CO2 emission rate and fuel efficiency forecasts
- Updated criteria technology penetration (i.e., SULEV30, ULEV125)
- Updated in-use emission factors for vehicles certified to 3 and 1 mg/mi PM emission standards

2. INTRODUCTION

2.1. EMFAC2017

An emissions inventory is a critical element in the control of air pollution and the attainment of national and state ambient air quality standards. It is also an essential tool in developing regulations and control strategies to fulfill the California Air Resources Board's (CARB) mission to promote and protect public health, welfare, and ecological resources through the effective and efficient reduction of air pollutants while recognizing and considering the effects on the economy of the state.

An emissions inventory (for any source category) can be calculated, at the most basic level as the product of an emission rate, expressed in grams of a pollutant emitted per some unit of source activity, and a measure of that source's activity. The following expression illustrates this basic relationship between the emissions rate and source activity used to calculate emissions:

Emission Factor X Source Activity = Emissions

For on-road motor vehicles, emissions rates are typically expressed as mass of pollutant emitted per mile driven, per vehicle per day, or per trip made, depending on the emissions process being analyzed. An emissions process for a motor vehicle is the physical mechanism that results in the emissions of a pollutant (e.g., the combustion of fuel, the evaporation of fuel, tire or brake wear, or the start of an engine).

The California Air Resources Board (CARB) developed an EMission FACtors (EMFAC) model to calculate statewide or regional emissions inventories by multiplying emissions rates with vehicle activity data from all motor vehicles, including passenger cars to heavy-duty trucks, operating on highways, freeways, and local roads in California.

Over the years, tougher emissions standards have been met with technological solutions of increasing complexity. As a result, the emissions estimation models have also grown in size and complexity. EMFAC2017 is the latest emissions inventory model that calculates emissions inventories for motor vehicles operating on roads in California. EMFAC2017 represents the next step forward in the ongoing improvement process for EMFAC, and reflects the CARB's current understanding of how vehicles travel and how much they pollute. The EMFAC2017 model is needed to support the Air Resources Board's regulatory and air quality planning efforts and to meet the Federal Highway Administration's transportation planning requirements.

The EMFAC2017 model can be used to show how California motor vehicle emissions have changed over time and are projected to change in the future. This information helps CARB evaluate prospective control programs and determine the most effective, science-based proposals for protecting the environment. EMFAC2017 includes the latest data on California's car and truck fleets and travel activity. New forecasting methods have been incorporated for developing vehicle age distributions and estimating vehicle miles traveled. The model also reflects the emissions benefits of Federal and California recent rulemakings such as Federal Phase 2 Greenhouse Gas Standards. The model also includes updates to truck emission factors based on the latest test data.

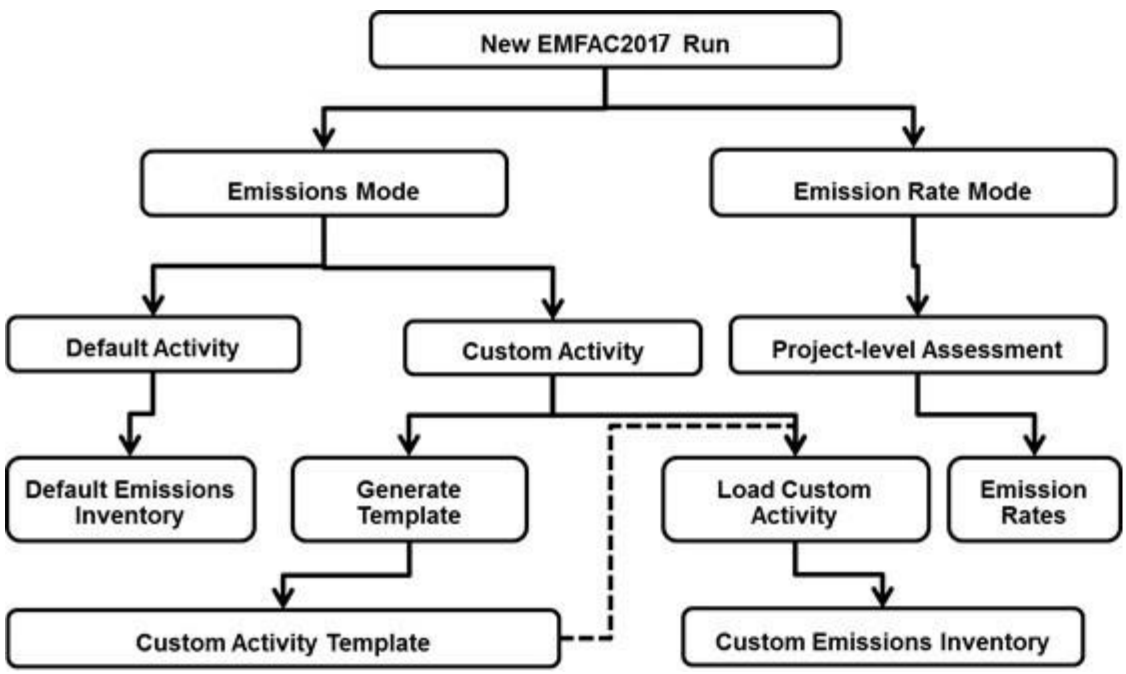
2.2.MODELING ARCHITECTURE

In EMFAC2014, CARB staff departed from using Fortran (the legacy programming tool that was used for previous versions of EMFAC) and rebuilt the model using Python and MySQL software. EMFAC2017 will use a similar framework as EMFAC2014. The use of a Python and MySQL based framework was done for several reasons:

- To make the model more user friendly;
- To make it easier to update the model code and associated data & methodologies into the future;
- To provide greater flexibility for incorporating and assessing future new rules;
- To provide the capability for developing more detailed emissions inventories;
- To make it easier to transfer EMFAC output to other tools.

Figure 2.1-1 displays a flow chart indicating the GUI selections necessary to generate the various outputs of EMFAC2017. The Emissions Mode can be used to estimate tons of emissions per day and the Emission Rate Mode, which can be used to estimate grams of emission per unit of activity, has been disabled.

Figure 2.1-1. EMFAC2017 Overall Flow



IMPORTANT! – "Custom Activity" Mode

The EMFAC2017 Custom Activity Mode can be used to produce emissions inventories for two specific types of assessments: conformity assessments and SB375 assessments.

For conformity assessments, emissions are estimated with all current controls active, except Low Carbon Fuel Standards (LCFS). The reason for excluding LCFS is that most of the emissions benefits due to the LCFS come from the production cycle (upstream emissions) of the fuel rather than the combustion cycle (tailpipe). As a result, LCFS is assumed to not have a significant impact on CO_2 emissions from EMFAC's tailpipe emission estimates.

For SB375 assessments, the Advanced Clean Cars (ACC)/Pavley rules are deactivated. Because the ACC regulation has certain assumptions about vehicle usage built into it, default data in custom activity templates produced for conformity assessments will not match the default data in templates for SB375 assessments. For the same reason, estimates of CO_2 will also differ.

2.3. MAJOR UPDATES

This section briefly summarizes the differences between EMFAC2017 and EMFAC2014. The major updates include the following.

Incorporation of most recent California vehicle registration data – CARB determines on-road vehicle population using data sets obtained from the California DMV. DMV data, along with BAR Smog Check data and VIN Decoder data, are used to assign vehicle classes and vehicle populations in the EMFAC model. EMFAC2017 incorporates DMV vehicle registration data from year 2000 – 2016. More details can be found in section 4.2.

Updated Vehicle Activity Profiles using data from California Household Travel Survey and extramural contracts – As part of EMFAC2017 development staff evaluated current assumptions in EMFAC model with respect to number of starts, VMT by speed distribution for different vehicle categories, cold/warm start temporal distribution, soak time and vehicle operation time distribution and updated those assumptions based on available data. More details are provided in section 4.4.

Update to light duty gasoline emission rates (sections 4.3.1)– EMFAC estimates tailpipe emissions, from light-duty (LD) vehicles, primarily using emissions data from vehicles driven on California Unified Cycle (UC). Base emission rates (BERs) for running exhaust (RE) emissions are derived from UC phase two (UC_{P2}) data and starts exhaust (SE) emission rates are currently based on UC phase one (UC_{P1}) data. EMFAC's LD UC BERs have not been updated since EMFAC2000. Since then, a variety of new of engine and after-treatment technologies have been incorporated into the LD fleet, altering the emissions of the vehicles. To improve the accuracy of EMFAC's LD emissions estimates, staff concluded that it was necessary to update UC BERs using the most recent, comprehensive data available. Three major updates were incorporated into EMFAC2017:

I. Staff updated EMFAC's RE emission rates by using new Federal Test Procedure (FTP) data from the US EPA's In-Use Verification Program (IUVP) and FTP and UC data from the CARB's Vehicle Surveillance Program (VSP). The IUVP's FTP results along with sales weighting data from the CARB's Certification NMOG Reports will be used to compute fleet emission regime fractions. UC_{P2} and FTP composite data, from the VSP, will be used to assign UC_{P2} emission rates to the emission regimes in each technology group.

II. Staff also updated EMFAC's SE emission rates by switching over to a new methodology that utilizes both UC_{P1} and Unified Cycle Phase 3 (UC_{P3}) BERs, updating these BERs with newly acquired data, and switching over to an emission group-based categorization of the starts technologies rather than a parts-based categorization. Soak factors, which are used to estimate warm start emissions, are also revised using VSP data which includes UC emissions data for trips following different length periods of soak.

III. Fuel efficiency in EMFAC2017 were updated using individual CO_2 emission factors obtained individually for each vehicle operating on-road in California based on the city and highway fuel efficiency data from EPA FuelEconomy.Gov database. Using this approach, staff was able to assign fuel efficiency data obtained FuelEconomy.Gov to nearly 95 percent of the CA vehicle population obtained from DMV2015b. Vehicle records included in this analysis involved post-2004 passenger cars and light duty trucks. Using this approach CO_2 emission rates for model years 2005 through 2015 were updated.

Revision of heavy-duty diesel (HD Diesel) truck emission rates – For EMFAC2017, staff utilized a variety of different data sources to update BERs, SCF, Starts and Idling emission factors for medium heavy-duty and heavy heavy-duty vehicles (above 14,000 lbs. GVWR). Compared to EMFAC2014, NOx and PM emission factors for heavy duty diesel trucks and buses are higher in EMFAC2017. In terms of emission deterioration, for EMFAC2017, staff has reviewed the information and data available regarding the in-use performance of SCR and DPF on a fleet-wide basis and made revisions when deemed necessary. As a result of these updates, staff made an adjustment to the frequency of all NOX and PM related TM&M categories for 2010+ MY engines. Staff also updated the emission rate increase associated with PM related TM&M. More details are provided in Section 4.3.2.

Greenhouse Gas Module – The EMFAC2017 model provides additional capability to come up with GHG emission estimates. A GHG module consistent with CARB's official methodology is developed and included in the EMFAC2017. The GHG module can generate emissions of the following three climate pollutants: CO_2, CH4, and N2O, as well as their CO_2 equivalents (CO_2e) based on GWP values from IPCC's Fourth Assessment Report (AR4).

Transit Module – To reach California's air quality and climate goals, CARB has recently proposed the Innovative Clean Transit measure to expedite the use of advanced technologies in transit buses. This requires an accurate account of emissions from this category. In response to the needs, EMFAC2017 incorporates a detailed transit module that accurately characterize activity and emissions from transit buses. Transit buses, namely, the "urban buses" category in EMFAC, covers a mix of vehicles that are diverse in body types, fuel types, and weight class. Previous versions of EMFAC model only differentiate transit buses by fuel type. The new module differentiates transit buses by body type and weight class in addition to fuel type, and associates each sub-category with appropriate useful life and emission rates. We also updated transit bus emission rates by incorporating the latest testing data on diesel and CNG buses. More details can be found in sections 3.2 and 4.3.2.4.

Natural Gas Module – Unlike EMFAC2014 model and prior versions that only provided emissions of gasoline and diesel vehicles, EMFAC2017 allow the users to estimate emissions of natural gas powered vehicles in addition to gasoline and diesel. This new module estimates the fraction of natural gas vehicles among heavy duty truck population at the air district level and applies it to diesel heavy duty truck outputs to produce natural gas heavy duty (NGHD) vehicle emissions and activity outputs. Although NGHD vehicles have different emission characteristics compared to those of diesel vehicles, the current module treat emissions from NGHD vehicles the same as diesel heavy duty trucks. It needs to be noted that this module is still an experimental feature of the EMFAC model which only works under “emission” mode. Upon availability of appropriate emission test data, this natural gas module will be improved in future versions of the EMFAC model. More details can be found in section 3.3.

Regulatory Impact – EMFAC2017 also reflects state and federal laws, regulations, and legislative actions that were adopted as of December 2017. These regulations and policies includes:

I. *Phase 2 GHG standards* – The Phase 2 standards are the second phase of federal heavy–duty GHG standards and build upon the Phase 1 standards. The regulation imposes new requirements for newly manufactured compression and spark ignited engines in Class 2b through Class 8 vehicles. Phase 2 requirements begin with model year 2018 for trailers and model year 2021 for engines and vehicles, and phase–in through 2027 model year.
II. *Senate Bill 1* - SB 1, The Road Repair and Accountability Act of 2017, requires the Department of Motor Vehicles (DMV), starting January 1, 2020, to verify that a medium-duty or heavy-duty vehicle is compliant with or exempt from CARB’s Truck and Bus Regulation before allowing registration.

A complete discussion of all the updates can be found in chapters 3 and 4.

2.4. ACCESSING DATA THROUGH WEB DATABASE

The web based inventory data query tool[7] was a feature that was first released with EMFAC2011. For the majority of users, the EMFAC2011 web-based data provided easy access to EMFAC2011 default emission inventories without the need to actually run the model. EMFAC2017 also provides web-based inventory data sets which utilize the default activity data of EMFAC2014’s Default Activity Mode runs. The EMFAC2017 web-based inventory data query

[7] http://www.arb.ca.gov/emfac/

tool web page will also be updated with activity data provided by planning agencies to use in place of the EMFAC2014 default activity data.

3. NEW MODULES IN EMFAC2017

3.1. THE GREENHOUSE GAS (GHG) MODULE

3.1.1. BACKGROUND AND OVERVIEW

One of EMFAC2017's new features is the greenhouse gas (GHG) module. EMFAC2017 accommodates the first-ever GHG module which provides additional capabilities to calculate on-road mobile source GHG emissions. CARB's official GHG inventory for 2012 shows that carbon dioxide (CO_2) accounts for 98.8 percent of on-road GHG exhaust emissions, followed by nitrous oxide (N_2O; 1.0 percent) and methane (CH_4; 0.2 percent), in CO_2-equivalent[8]. Calculation of GHG emissions is improved in EMFAC2017 in order to support CARB's GHG Emission Inventory, Scoping Plan, Sustainable Freight Strategy, and regulatory development.

CO_2 emission rates in EMFAC2014 and prior versions were calculated based on vehicle testing data, which does not represent CARB's official method of calculating GHG emissions. In contrast, EMFAC2017 will estimate CO_2 emission rates based on complete combustion of transportation fuels, as is consistent with the official CARB, U.S. EPA, and IPCC methodologies. EMFAC2017 will also update CH_4 calculations based on the latest available vehicle testing data.

N_2O was not estimated in EMFAC2014 and prior versions while the methodology was available so it can be calculated off-model using NOx or fuel as a surrogate. In EMFAC2017, gasoline N_2O will be estimated as a function of NOx emissions based on the latest vehicle testing data; diesel N_2O will be estimated using the existing fuel-based approach but with an improved emission factor, which is derived from the most recent heavy duty vehicle testing data.

The new addition of the GHG module to EMFAC2017 will handle in one single place the three greenhouses: CO_2, CH_4, and N_2O. Furthermore, this module is also able to report their CO_2 equivalents (CO_2e) using IPCC AR4's global warming potential (GWP) values, in order to be consistent with CARB's latest official GHG inventory.

3.1.2. DATA SOURCES

There are several data sources used to calculate GHG emissions in EMFAC:

I. *California Board of Equalization (BOE)* provides volume data for total gasoline blend, total diesel blend, biodiesel, and renewable diesel sold in California.

II. *California Energy Commissions (CEC)* provides the percent of ethanol in the gasoline blend through 2010, while CARB's MRR reports ethanol gallons for 2011+.

---

[8] "Carbon dioxide equivalent" or "CO_2e" is a term for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gas, CO_2e signifies the amount of CO2 which would have the equivalent global warming impact.

III. The default emission factors and heat content are from CARB's Mandatory Reporting Requirement (MRR) and U.S. EPA.

IV. CH_4 emissions rates were determined from data collected through CARB's vehicle surveillance program (VSP) for light duty vehicles.

V. N_2O and NOx emissions rates are determined from CARB's VSP for gasoline vehicles and CARB's Cross California PEMS data for heavy duty vehicles.

3.1.3. CO_2 ESTIMATION: A FUEL BASED APPROACH

In EMFAC2017, CO_2 is estimated based on fuel consumption assuming complete combustion. Complete combustion means that a fuel is burned completely and all carbon content of the fuel is eventually converted to CO_2. This aligns with the methodology used for CARB's official GHG inventory. The new approach disaggregates fuel blends into major components, and thus, CO_2 emissions from each of the fuel components are calculated individually. Total CO_2 emissions are simply the sum of those from each component.

Considering gasoline-ethanol blend as an example, the proportions of pure ethanol and pure gasoline in this blend have changed throughout years. Those other than pure ethanol contained in the denatured ethanol would just fall under pure gasoline for purposes of estimating CO_2 emissions from it. Generally, most transportation fuels consist of a blend of fossil-derived component and bio-derived or renewable component. Proportions of fuel component vary with year. Below is the current level of fuel blend proportions, on a volume basis:

- Gasoline fuel blend contains ~10 percent ethanol; and
- Diesel blend contains ~6 percent biodiesel and renewable diesel components.

The fuel blend component approach recognizes the increasingly important role of combustion of biofuels (ethanol, biodiesel, renewable diesel, etc.). It also allows for accommodating future emerging fuel components in a fuel blend and tracking for upstream analysis. Below is a general equation for calculating CO_2 from each component of a fuel blend (e.g., gasoline or diesel). This equation also applies to natural gas vehicles, although natural gas is typically measured in standard cubic feet (scf) instead of gallons.

CO_2 = **Fuel Consumption** (gal) * **Blend Proportion** (%) * **CO_2 Emission Factor** (g/BTU) * **Heat Content** (BTU/gal)

Where,

CO_2: CO_2 emissions of gasoline (or diesel) vehicles for a particular vehicle type (grams);

Fuel Consumption: Fuel consumption for a particular gasoline (or diesel) vehicle type (gallons). The "fuel" is a blend of components, typically;

Blend Proportion: The volumetric proportion of the component in the fuel blend (%);

CO_2 Emission Factor: CO_2 emission factor by combustion of the fuel component, assuming complete combustion (grams CO_2 / BTU); and

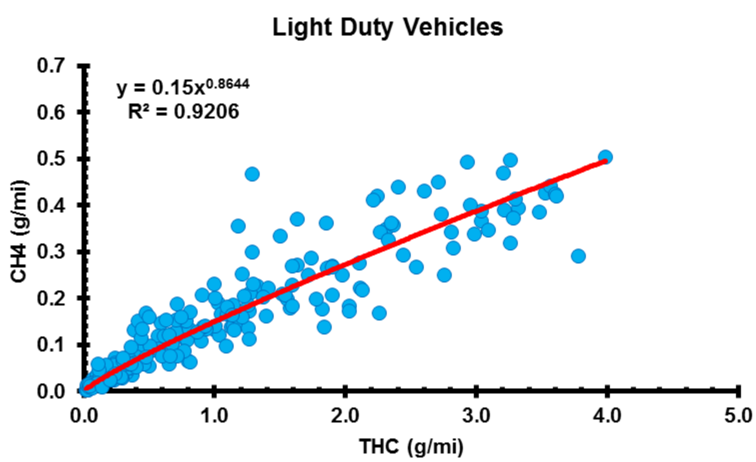
Heat Content: Heat content of the fuel component; i.e., annual average higher heating value (HHV) of the fuel component (BTU/gallon).

3.1.4. CH_4 ESTIMATION

Methane (CH_4) is another important GHG pollutants and so its emissions need to be quantified. In EMFAC2014, CH_4 was estimated using HC speciation profiles[9]. However, due to availability of CH_4 emission data beyond speciation tests, staff decided to update THC to CH_4 conversion factors based on a higher number of vehicle test data.

CH_4 exhaust emission rates can be calculated as a function of THC emission rates, on a mass (grams/mile) basis. To develop a regression equation for the relationship between exhaust CH_4 and THC in gasoline powered vehicles, FTP composite data from VSP were used. Recent testing data were statistically analyzed by fitting the data to an exponential function. A few outlier data points were removed in order to develop the most representative relationship between CH_4 and THC emission rates. To keep the data sample size sufficiently big, we only removed data points that were well outside of the reasonable range of the CH_4 – THC relationship. Also, removing outliers provides further confidence that the developed regression equations are a good representative of typical emission rates, rather than an extreme emission case. Testing data points and developed equations are show in Figures 3.1-1 and Table 3.1-1.

Figure 3.1-1: FTP Composite emission rates of CH4 and THC exhaust from gasoline LDVs



For diesel and natural gas vehicles, CH_4 emission rates are calculated from THC using the speciation profiles approach (the existing approach). Current testing data that obtained by CARB indicate that emission rates of CH_4 and THC from diesel trucks do not have a reasonable correlation. Table 3.1-1: shows equations for calculating CH_4 emission rates for some vehicle/fuel categories.

[9] http://www.arb.ca.gov/ei/speciate/speciate.htm

Table 3.1-1: Equations for calculating CH4 emission rates from THC emission rates

Fuel	Model Year	Proposed approach	Data Source
Gasoline	All	$CH_4 = 0.15 * THC^{0.8644}$	CARB's VSP
Diesel	All	$CH_4 = 0.059 \times THC$	EMFAC2014
Natural Gas	2006 and Prior	$CH_4 = 0.90921 \times THC$	
	2007+	$CH_4 = 0.97788 \times THC$	

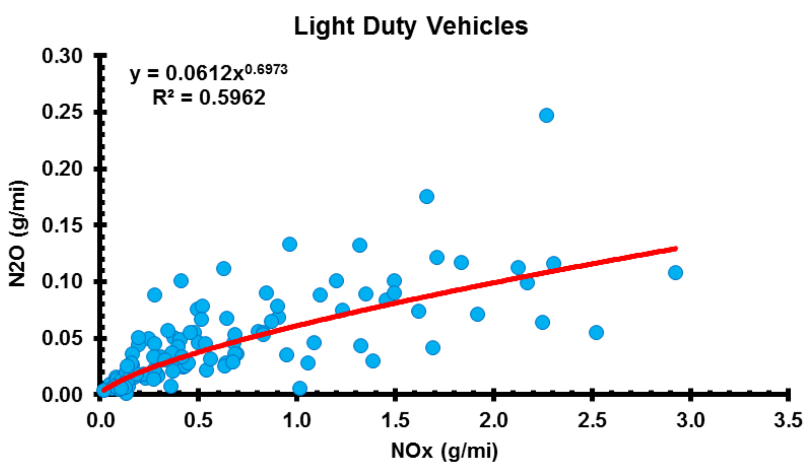
CH_4: CH_4 emission rate in (g/mi) and THC: THC emission rate in (g/mi).

3.1.5. N_2O ESTIMATION

Nitrous oxide or N_2O is another important GHG pollutant that has a significant global warming potential. On a per-mass basis, considered over a 100-year-period, nitrous oxide has 298 times the atmospheric heat-trapping ability of carbon dioxide. Emissions of Nitrous oxide were not estimated in EMFAC2014 and prior versions. In EMFAC2017, N_2O emission rates are estimated from NO_x emission rates using a regression equation that is developed using FTP composite data collected through vehicle chassis dynamometer testing.

Recent testing data from CARB surveillance programs were statistically analyzed by fitting the data to an exponential function. A few outlier data points were removed in order to develop the most representative relationships between N_2O and NOx composite emission rates. Testing data points and the fitted equation are shown in Figure 3.1-2.

Figure 3.1-2: FTP Composite emission rates of N2O and NOx from gasoline vehicles



For diesel vehicles, emission rates of N_2O are calculated from diesel fuel consumption. The approach suggested on CARB mobile source emission inventory (MSEI) website[10] used 0.332 g N_2O per gallon diesel consumed; however, analysis of the most recent emission data obtained from CARB's Cross California truck testing campaign indicates that the prior factor (i.e., 0.332 g/gal of diesel) significantly underestimated the N_2O emissions from heavy duty diesel vehicles.

[10] https://www.arb.ca.gov/msei/emfac2011-faq.htm#emfac2011_web_db_qstn07

In EMFAC2017, an improved emission factor of 1.60 gN_2O per gallon of diesel is used to calculate N_2O emissions from diesel vehicles.

Table 3.1-2 shows equations for calculating N_2O emission rates from gasoline passenger cars (PC) or diesel heavy duty (HD) vehicles.

Table 3.1-2: Equations for calculating N_2O emission rates from NOx emission rates

Fuel	Proposed approach	Data Source
Gasoline	$N_2O = 0.0612 \times NO_x^{0.6973}$	CARB's VSP
Diesel	1.60 gN_2O per gallon of diesel	CARB's Cross California

N_2O: N_2O emission rate (g/mi) and NO_x: NO_x emission rate (g/mi).

3.1.6. CO_2 EQUIVALENT (CO_2E)

The GHG module calculates and reports emissions of CO_2, CH_4, and N_2O not only in direct tonnage, but also in their CO_2 equivalents (CO_2e). To be consistent with CARB's latest official GHG inventory, the global warming potential (GWP) values used in EMFAC2017 correspond to IPCC AR4's 100-year time horizon. In particular, the GWP values are as follows: 25 for CH_4 and 298 for N_2O.

3.1.7. PROGRAMMING IMPLEMENTATION

EMFAC2017 users are now presented with the option to estimate GHG emissions using EMFAC. This feature can provide GHG emissions and fuel consumption for an average weekday or annually.

The output of GHG module is an independent file containing CO_2, CH_4, and N_2O emissions, as well as fuel consumption. Also included are daily and annual CO_2e emissions based on IPCC AR4 GWP values for the 100-year horizon (to be consistent with CARB's official GHG inventory).

The units for the output file are described below:

- Columns "emission", "emission_annualized", and "CO_2e" are in units of tons (and in thousand gallons where the reported pollutant is Fuel). This is to be consistent with the EMFAC model's historical convention; i.e., all emissions are in short tons and fuel consumption is in thousand gallons.
- Column "CO_2e_annualized" is in metric tons. Note that 1 ton = 0.907185 metric tons. Using these units facilitates comparisons with much of the existing literature, which reports CO_2e in metric tons or million metric tons such as those reported in CARB's Scoping Plan.

3.1.8. UPDATES TO LD FUEL EFFICIENCY (HISTORICAL AND FORECAST)

EMFAC includes a module that estimates and projects total CO_2 emissions from on-road light-duty vehicles. Historically, emissions from these vehicles has been largely driven by Federal Corporate Average Fuel Economy (CAFE)[11] standards first enacted in 1975. In 2004, California approved GHG emission standards for new light-duty vehicles, for which EPA granted a waiver to implement these standards in 2009. EMFAC2014 incorporates the standards that apply to model years 2009-2016 vehicles. In conjunction with the waiver approval, California, U.S. EPA, and the National Highway Traffic Safety Administration (NHTSA) committed to developing harmonized GHG and CAFE standards for model years 2012-2016. As part of this agreement, California adopted the “deemed to comply” provision allowing manufacturers the option of complying with federal GHG standards in lieu of California’s requirements. One major difference between California’s emission standards is that the federal GHG and fuel economy standards are a footprint based standard. Hence, GHG emission targets for individual manufacturers will vary based on their specific mix of vehicle footprints, rather than all vehicles of a particular category being subject to a uniform standard. EMFAC2014 was the first model to include both California and the new federal standards to estimate past and future CO_2 emissions.

For EMFAC2017, emission standards were updated to reflect the Advanced Clean Cars program that will apply to new vehicles in model years 2017-2025. Additionally, the methodology for estimating historic and future CO_2 emissions was updated to more accurately reflect these recent standards. In the absence of historic vehicle CO_2 emission data, CARB staff developed a database tool that links DMV vehicle registration data to EPA fuel economy data obtained from FuelEconomy.Gov, to estimate city and highway CO_2 emission rates for each vehicle operating on road in California. Results of this analysis are summarized in the continuation of this section and the methodology is discussed next.

3.1.8.1. METHODOLOGY

Since EMFAC2007, the fuel usage estimates have been made using a carbon balance method, which means that the emissions results for carbon containing species such as carbon dioxide, carbon monoxide, and total hydrocarbons or volatile organic compounds were used to determine the amount of fuel combusted. EMFAC2017 still uses the same approach, however, a more refined methodology for calculation of the total CO_2 emissions is used. This version of EMFAC calculates the total CO_2 emissions using individual CO_2 emission factors obtained for each vehicle operating on-road in California based on the city and highway fuel efficiency data from EPA FuelEconomy.Gov database.

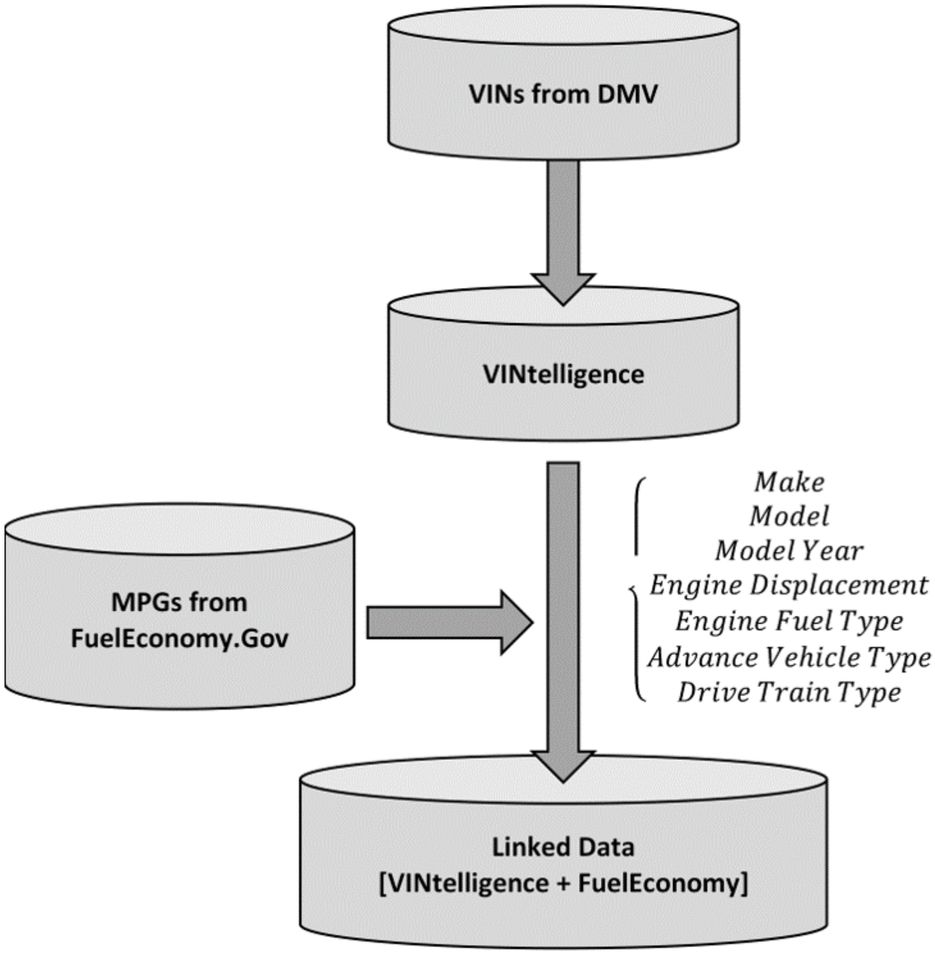
A summary of the approach is illustrated in Figure 3.1-3. The analysis starts with obtaining all the vehicle records from the DMV database. Vehicle specifications such as make, model, model year, engine displacement (Displ), number of cylinders (Cyl), fuel type, emission standards, advanced vehicle type, and drivetrain type (Drive) are obtained from Polk/IHS VINtelligence

---

[11] The CAFE Standards. The Library of Congress Congressional Review Service. Report CRS 90122. http://assets.opencrs.com/rpts/IB90122-20030312.pdf

service and are appended to the DMV vehicle records. The appended specifications are then used to find a match for each DMV vehicle record in the EPA FuelEconomy.Gov. The two databases are linked this way, and hence, the city and highway fuel efficiency can be appended to the DMV records as well.

Figure 3.1-3: A diagram illustrating steps involved in obtaining fuel efficiency (MPG) data for DMV vehicle records using Polk/IHS VINtelligence service and FuelEconomy.Gov database



Next, since the majority of the published EPA fuel efficiency values are based on 5-cycle driving tests, the following two formulae have been used to convert the fuel efficiencies to the 2-cycle basis (FTP and HFET cycles):

- 5-Cycle City MPG = 1/ (0.004091 + 1.1601/FTP MPG)
- 5-Cycle Highway MPG = 1/ (0.003191 + 1.2945/HFET MPG)

  Where:
- *5-Cycle City MPG*: EPA 5-cycle fuel efficiency for city driving
- *5-Cycle Highway MPG*: EPA 5-cycle fuel efficiency for highway driving

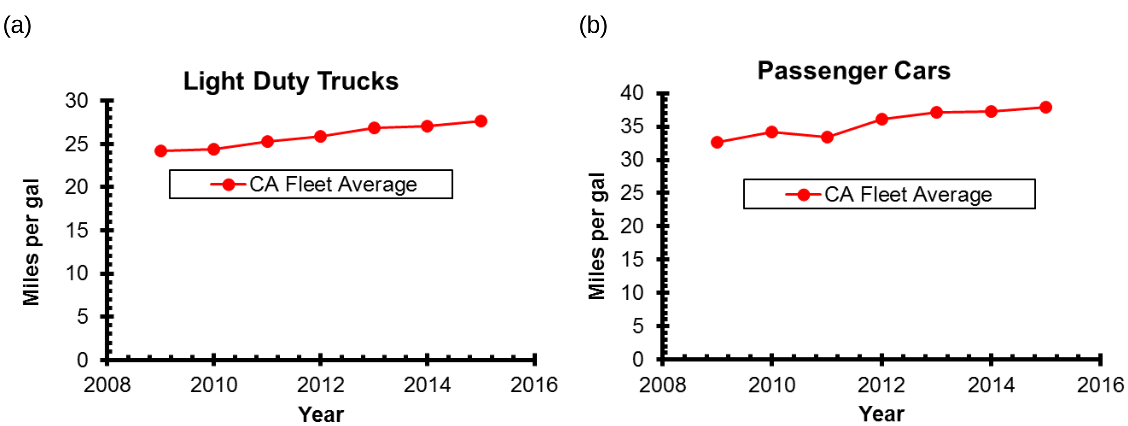
- *FTP MPG*: Federal Test Procedure (FTP) composite equivalent fuel efficiency for city driving
- *HFET MPG*: Highway Fuel Economy Test (HFET) Cycle equivalent fuel efficiency for highway driving

The FTP and HFET MPGs estimated above are then converted to CO_2 emission rates for city and highway driving, respectively. In addition, these two emission rates are combined using FTP composite (55 percent) and HFET (45 percent) CO_2 emission rates to estimate the combined driving cycle CO_2 emission rates. The combined driving cycle CO_2 emission rates can then be used by the underlying EMFAC2017 modules to estimate CO_2 emissions for the entire CA vehicle fleet. When CO_2 emission rates are calculated, the total amount of fuel usage can be estimated using the carbon balance approach.

3.1.8.2. RESULTS

Using this approach, staff were able to assign fuel efficiency data obtained from FuelEconomy.Gov to nearly 95 percent of the CA vehicle population obtained from the DMV vehicle registration database as of October 2015 (i.e., DMV2015b). Vehicle records included in this analysis involved model years 2004+ passenger cars and light duty trucks including LDT1, LDT2, and MDV. Results are shown in Figure 3.1-4. Subfigures (a) and (b) represent California fleet average fuel efficiency by vehicle model year in units of grams per mile traveled.

Figure 3.1-4: California Fleet Average Fuel efficiency by Model Year



3.1.8.3. PROJECTED CO_2 EMISSION RATES

The projected tailpipe CO_2 emission factors for gasoline vehicles were derived using the U.S. EPA Optimization Model for the Reduction of Greenhouse Gases from Automobiles (OMEGA)[12]. This model was previously used to support federal and California rulemakings in 2012 to regulate CO_2 emissions from the light-duty vehicle fleet. It projects future tailpipe CO_2 emission factors of light-duty cars and trucks for a given manufacturer in a given model year based on

[12] https://www.epa.gov/regulations-emissions-vehicles-and-engines/optimization-model-reducing-emissions-greenhouse-gases

fleet-wide CO_2 emission standards mandated by GHG regulations. These projections depend on user inputs specific to the future target model year including:

- Car and truck sales for each manufacturer
- The size (i.e. footprint) of the vehicles sold by each manufacturer
- The effectiveness of the GHG-reducing technology available to the manufacturers
- The cost for the manufacturers to install GHG-reducing technology on the vehicles
- Manufacturers' ability to trade CO_2 credits between their car and truck fleets
- The use of low GHG A/C refrigerants by the manufacturers, which generate CO_2 credits but do not impact tailpipe CO_2 emissions

In addition to these inputs, the presence of any ZEV mandate will impact the projected CO_2 emission factors for gasoline vehicles in that manufacturer's fleet. The California ZEV mandate, for example, requires a certain percentage of ZEV sales in most manufacturer fleets and these ZEV sales impact the final tailpipe CO_2 emission rates achieved by gasoline vehicles in each of the manufacturer fleets. Specifically, the more ZEVs a manufacturer has in its fleet, the less improvements need to be made to gasoline vehicles because the ZEVs will reduce the fleet wide CO_2 average emission factor much more than gasoline vehicles alone. Accordingly, CO_2 emission factors for gasoline vehicles in a manufacturer's fleet can be higher, on average, with ZEV mandate requirements.

Based on these inputs, OMEGA will calculate the most cost-effective compliance path for each manufacturer to meet their combined car/truck CO_2 emission targets. Once this is done, OMEGA provides a description of the technologies present on each of the vehicles in the manufacturers' fleets and the tailpipe CO_2 emissions associated with the vehicles in the fleet. These data can be used to calculate fleetwide tailpipe CO_2 emission factors for cars and trucks.

For this analysis, staff used OMEGA to calculate tailpipe CO_2 emission factors in model years 2021 and 2025 (only two model years) based on assumptions used in the 2016 US EPA Proposed Determination on the Appropriateness of the Model Year 2022 – 2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation[13]. Slight updates were made to model inputs to reflect revised estimates of ZEV sales (due to the California ZEV mandate) in 2021 and 2025. In addition, the 2-cycle emission results were further adjusted to account for differences between 2-cycle CO_2 emission results used in OMEGA and real-world CO_2 emission levels and are described in the Proposed Determination documentation[14]. The CO_2 tailpipe emissions for other model years between 2016 and 2025 were derived by linear interpolation. Using these emission factors, staff calculated CO_2 reduction factors with respect to MY2004 (Table 3.1-3) and the projected CO_2 emission rates in EMFAC2017 have been updated using these reduction factors.

---

[13] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100Q3DO.pdf
[14] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100Q3L4.pdf, Section 3.1.2

Table 3.1-3: Updated CO2 Reduction Factors in EMFAC2017

Vehicle Model Year	Reduction Factor for Passenger Cars	Reduction Factor for Trucks
2004	1.00	1.00
2005	0.96	0.98
2006	0.98	0.96
2007	0.94	0.94
2008	0.91	0.92
2009	0.89	0.86
2010	0.85	0.86
2011	0.88	0.83
2012	0.80	0.81
2013	0.78	0.78
2014	0.78	0.78
2015	0.77	0.76
2016	0.74	0.73
2017	0.72	0.70
2018	0.70	0.67
2019	0.68	0.64
2020	0.66	0.61
2021	0.63	0.58
2022	0.61	0.55
2023	0.59	0.53
2024	0.56	0.51
2025+	0.54	0.49

3.2.THE TRANSIT BUS MODULE

3.2.1. BACKGROUND

Transit buses, categorized as “urban buses” in EMFAC, are on-road vehicles that are operated by public transit agencies to provide public transit service, including fixed-route and demand response services. Starting 2000, heavier transit buses with gross vehicle weight rating (GVWR) 33,000 lbs. and above were subject to CARB’s Fleet Rule for transit agencies[15]. To reach California’s air quality and climate goals, CARB has recently proposed the Innovative Clean Transit measure to expedite the use of advanced technologies in transit buses. This requires an accurate account of emissions from this category.

Previous EMFAC models used DMV vehicle registration data as the primary source of historical transit bus population. However, since a transit bus is only required to register once and registration data stay in the DMV database afterward regardless of the status of the bus, the DMV data may include buses that are no longer in service. This leads to over-estimation on

---

[15] https://arb.ca.gov/msprog/bus/bus.htm

transit bus population and VMT. In addition, the age distribution is biased toward older buses, which are associated with higher emission rates.

The new module uses the National Transit Database (NTD) from the Federal Transit Administration (FTA) for historical transit bus population and activity. The NTD was established as required by Congress to be the nation's primary source for information and statistics on the transit systems of the United States. Statute requires transit agencies to report to NTD annually if they receive or benefit from §5307 or §5311 formula grants. These reports provide rich and detailed transit fleet activity data for emission modeling purpose, including vehicle make, model year, fuel type, capacity, number of active vehicles, annual miles driven for each transit agency and by mode of service.

With the more detailed activity data from NTD, the new transit module differentiates transit buses by body type and weight class in addition to fuel type, and associates each sub-category with appropriate useful life and emission rates. We also incorporated updated transit bus emission rates developed from the latest testing data on diesel and CNG buses, which is discussed in detailed in section 4.3.2.4 of this document.

3.2.2. FORMULATION OF THE TRANSIT BUS MODULE

The transit bus module is constructed to handle buses of different fuel types, body types, and weight classes. The categories included in EMFAC2017 are listed in Table 3.2-1. While the module internally calculates the emissions for each individual category, it aggregates activity and emissions into one single vehicle category, that is, urban buses (UBUS), in the final EMFAC outputs.

The module includes two major data components: activities and emission rates. The activity includes historical data from NTD, and the forecasted activity using growth assumptions that are based on either transit growth estimated by metropolitan planning organization (MPO) or human population growth rates provided by California Department of Finance. The activity data is preprocessed as one input table for EMFAC2017. The emission rates are specified by vehicle weight class and fuel type. Depending on the weight class and fuel type, the data source or assumption varies as discussed in detail in section 3.2.3.2.

Table 3.2-1: Transit Bus Fuel Types, Weight Classes, and Body Types

NTD Field	Value and Criteria
Service Type	Bus (MB), Commuter Bus (CB), Demand Response (DR), Bus Rapid Transit (RB), Vanpool (VP)
Body Type	Articulated Bus, Bus, Cutaway, Double Decker Bus, Over-the-road Bus, Van, Other
Fuel Type	CNG, Diesel, Battery Electric Bus (BEB), Gasoline, Diesel Hybrid, Gasoline Hybrid, fuel cell electric bus (FCEB), Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG)
Seating Capacity	Greater or equal to 12

3.2.3. METHODOLOGY

3.2.3.1. TRANSIT BUSES ACTIVITY

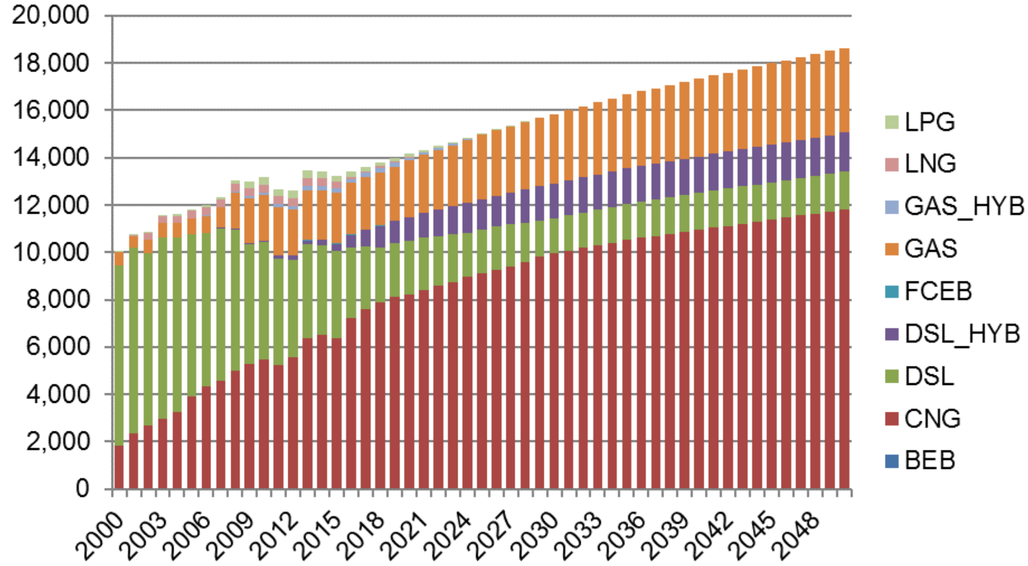
Staff processed the 2000-2015 annual NTD revenue inventory data to generate historical transit bus population and VMT. Depending on the funding source, urban transit agencies and rural transit agencies have different reporting requirements. Staff include both urban and rural reports and filter the data based on a set of criteria including service type, vehicle type, seating capacity, as shown in Table 3.2-1. The vehicle weight class is determined based on empirical data of vehicle make, model, length, and manufacture stated GVWR.

As rural agencies have less reporting requirements, rural transit data does not include fuel type, model year, among others. To address this issue, a hole-filling algorithm was employed to use the closest urban fleet data as possible (i.e., the fleet information from a similar transit agency was used as a surrogate to determine fleet characteristics – fuel type, model year – for those agencies that do not have complete data). In addition, rural transit inventory data are not available prior to 2007 so the fleet inventory and VMT between 2000 and 2006 were back-casted from 2007 rural data using the growth rate of urban transit fleets during these years.

On forecasting future transit activities, there are two major components: total growth by region, and the distribution of new purchase by fuel type and technology. First, the growth of future population and VMT were forecasted at regional level from the 2015 NTD data using region-specific growth rates. For areas governed by an MPO that forecasts transit growth in target years of the Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS), the growth rate is generated by linear interpolation of the growth between the base year and target years. For areas that are not covered by an MPO, or where local MPO does not provide transit growth, the county-level human population growth rate published by the Department of Finance were used as surrogate for transit growth. In the event that human population growth rate is less than 1, which means a county's population shrinks, we limit the transit growth to stay flat.

The second component of forecasting is estimating the transition between fuel types and between technologies in new purchases. The total new purchase each year is estimated as the difference of current year's new population and last year population after attrition. The attrition assumption assumes transit buses have a fixed life span and will be removed from the service after their useful life. For lighter vehicles with GVWR less than 14,000 lbs., the useful life is assumed to be 10 years, and for the rest of vehicles, the useful life is assumed to be 14 years. The new purchases are estimated for gasoline vehicles and non-gasoline vehicles separately. For non-gasoline new purchases, the fuel type split between diesel and CNG is determined based on region-specific natural gas penetration trend as discussed in EMFAC2014 technical support documentation (section 3.3.4.4.1 of EMFAC2014 Technical Support Document). It was assumed that 50 percent of all new diesel buses purchases are hybrid diesel buses, which have 25 percent fuel efficiency improvement. Given the absence of regulatory requirement, it is also assumed that there will be no new purchase of zero-emission buses. Figure 3.2-1 illustrates the population growth by fuel type.

Figure 3.2-1: Statewide Total Transit Buses Population by Fuel Types



3.2.3.2. TRANSIT BUSES EMISSION RATE

In EMFAC2017 we incorporated new emission rates for diesel and CNG heavy duty buses developed from multiple sources of testing data, as discussed in section 4.3.2.4. For the rest of fuel types or weight classes, certain assumptions were applied as listed under Table 3.2-2.

Table 3.2-2: Emission Rate assumptions for EMFAC2017 Transit Module

Weight Class	Fuel Type	Data Source and Assumption
Medium- and Heavy-Heavy Duty Trucks (MHDT & HHDT)	CNG	HHD based on new test; MHD scaled from HHD
	Diesel	HHD based on new test; MHD scaled from HHD, apply 85% PM emission reduction on older buses starting 2010 to account for PM filter retrofit
	BEB and FCEB	Zero tailpipe emissions
	Gasoline	Same as EMFAC2014 gasoline UBUS
	Diesel Hybrids	25% fuel efficiency improvement based on DSL
	Gasoline Hybrids	Same as EMFAC2014 Gasoline
	LNG	Same as CNG
	LPG	Same as CNG
	Low NOx CNG	90% lower NOx emission rate based on CNG UBUS
	Low NOx Diesel	90% lower NOx emission rate based on diesel UBUS
Light Heavy Duty Trucks (LHDT)	CNG, DSL, LNG, LPG	Same as EMFAC2017 diesel LHDT2 emission rates
	Diesel Hybrids	25% fuel efficiency improvement based on DSL LHDT2
	Gasoline, Gasoline Hybrids	Same as EMFAC2017 gasoline LHDT2 emission rates

3.3. THE NATURAL GAS MODULE

3.3.1. BASICS

Natural gas heavy duty (NGHD) trucks have been growing in California as they are considered to be relatively cleaner than conventional diesel or gasoline trucks and, therefore, some districts mandate or encourage public and private fleets to purchase NGHD vehicles. To address this growing NGHD fleet, EMFAC now includes a module for estimating emissions and activities of NGHD trucks. The module estimates the fraction of NG vehicles among HD truck population at the air district level and applies it to diesel HD truck outputs to produce NGHD emissions and activity outputs. Although NGHD trucks have different emission characteristics compared to those of diesel vehicles, the current module treat emissions from NGHD trucks the same as diesel HD trucks due limited availability of NGHD truck emission test results. Because of this limitation, the NGHD module should be considered as experimental. CARB along with several other government agencies are pursuing a contract to test a relatively large sample size of NGHD vehicles under a variety of different cycles. For future versions of the EMFAC model, testing results from this contract will be incorporated to produce more realistic estimates.

3.3.2. METHODOLOGY

The NGHD module was developed largely in four steps: 1) collecting NGHD truck population from California Department of Motor Vehicle (DMV), 2) analyzing NGHD-related policies across the state, 3) characterizing air districts in four classes for predicting their NGHD population in the future, and 4) estimating NGHD emissions and activity outputs from diesel HD trucks.

First, NGHD vehicle population was mainly obtained from California Department of Motor Vehicle (DMV) registration data tables. Vehicles that are currently registered or have evidence of use or pending registration were included. In addition to the DMV data, vehicles reported in the International Registration Program were also included if they were not found in the DMV data.

Second, the collected NGHD vehicle population was analyzed at the air district level. NGHD related rules and regulations are mostly developed at the air district level, which is one of the most important factors that would decide future population of NGHD trucks. Therefore, the air district level was chosen, although EMFAC performs emissions calculations at the Geographic Area Index (GAI) level. Note that GAI corresponds to a sub-area with a unique combination of County, Air District, and Air Basin. In addition, modeling the NGHD vehicles at the air district level result in a significantly larger sample size compared to the GAI level, which produces less noise and geographically more consistent distributions.

Third, air districts were categorized into four prediction classes after considering the historical population and the current and future regulations in each air district. The four classes were defined as follows:

- Linear growth: NGHD trucks are expected to increase in a linear manner. Their fraction can go up to 100 percent or a certain level, depending on applicable rules and regulations.
- Flat with 8-year average: the fraction of NGHD truck population relative to diesel HD trucks would remain as the average fraction in the past 8 years.
- Flat with 5-year average: the fraction of NGHD truck population relative to diesel HD trucks would remain as the average fraction in the past 5 years.
- Zero: no NG trucks have penetrated in the past or are expected to penetrate the future.

Details of NGHD penetration at each air district is provided in Appendix 6.3.

Fourth, emissions and activity of NGHD trucks were calculated using the NGHD fraction in each air district. As mentioned above, emission rates that are specific to NGHD trucks were not taken into account because emission testing data of NGHD trucks did not exist yet. The module simply applies the estimated population fraction of NGHD to diesel HD truck outputs to produce outputs for NGHD trucks. In the future, NGHD-specific emission rates will be incorporated when such testing data are obtained. Therefore, current NGHD outputs should be considered as experimental and interpreted carefully.

4. METHODOLOGY UPDATE

4.1. INTRODUCTION

This chapter discusses the updates that have taken place between EMFAC2017 and EMFAC2014. The methodological changes can be broken up into four broad categories, by which the chapter is divided: update to fleet characteristics (Section 4.2), emission rate updates (Section 4.3), activity updates (Section 4.4), and updates to forecasting assumptions (Section 4.5).

Update to fleet characteristics include the methodology used in developing the LD and HD vehicle population and age distribution matrices used in EMFAC2017. Derivation of accurate vehicle populations is critical to the construction of reliable emissions inventories.

Emission rate updates not only include changes in basic emission rates, but also changes to any associated correction factors for those basic emission rates. For example, changes in speed, temperature or relative humidity can all affect the emission rates and thus requires that correction factors be applied to emission rates (as appropriate). Emission rate and associated correction factor updates have been made mainly for exhaust emission process. For the most part, these emission rate updates are independent of any activity assumptions, with the exception for some processes that exhibit deteriorated emissions as vehicles age. The impetus for these emission rate updates included: new or amended regulations, availability of new data, new methodologies that were developed, or simply a need to fix errors from previous model versions.

Activity updates were made to mileage accrual rates, speed distributions, soak time distributions, idle time duration, and other parameter variables that describe how vehicles are utilized. Activity changes can be very dynamic because they are influenced by the economy and human behavior.

EMFAC2017 utilizes similar methodology as in EMFAC2014 to forecast vehicle population and vehicle miles traveled for both light and heavy duty vehicles. However, with the availability of updated socio-economic data, staff revisited the regression equations that were used to estimates future new vehicles sales and VMT and adjusted those to reflect the most recent economic forecast data.

4.2. FLEET CHARACTERISTICS

4.2.1. BASICS

This section discusses major updates to EMFAC2017 fleet characterization and describes changes in the methodology, tools, and data sources utilized to characterize the vehicle population in California. It also compares the fleet vehicle counts as modeled by EMFAC2014 against that of EMFAC2017. Twice a year California Department of Motor Vehicles (DMV) shares a copy of their vehicle registration data with CARB in April called ‘A’ Cut and in October called ‘B’ Cut.

EMFAC2017 uses the DMV 2016 'B' Cut as the main source of data for fleet characterization, and uses the data from the 'A' Cut to incorporate the latest changes in the fleet as seen by the DMV in April 2017. Each DMV data cut has roughly between 40 and 45 million vehicle records and includes approximately 100 data fields. In short, the fleet characterization entails the following steps. First, duplicate records are removed and only the latest vehicle record associated with each Vehicle Identification Number (VIN) are kept in the database. Then, vehicles are classified according to CARB Executive Orders issued for each vehicle make, model, and model year. And last, vehicle records are distributed among different geographical areas.

4.2.2. UPDATES TO LD FLEET CHARACTERISTICS

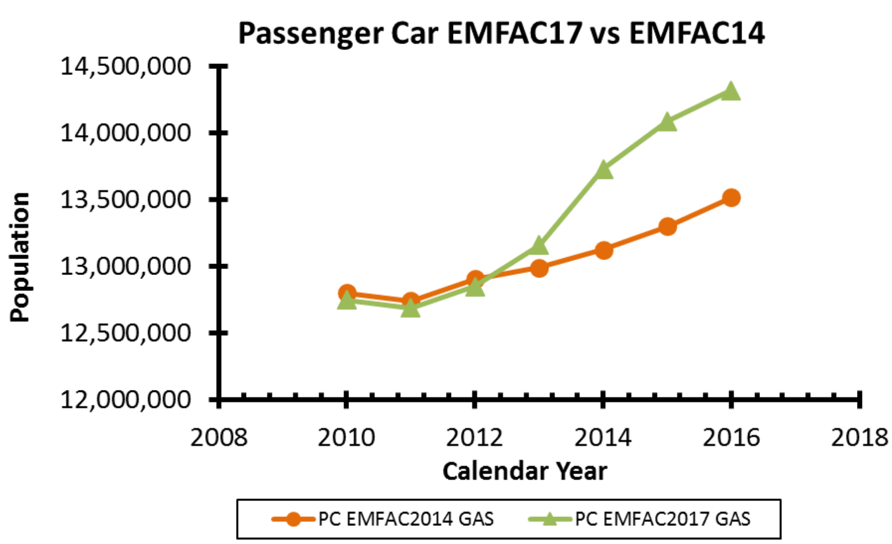
4.2.2.1. COMPOSITION OF THE FLEET IN CALIFORNIA

This section discusses the vehicle population trends in EMFAC2017 and the differences between the vehicle counts included in the EMFAC2017 and EMFAC2014 by fuel type and model year. It also presents the trends seen in the new vehicle sales of passenger cars (PC), light duty trucks (LDT), and light heavy duty trucks (LHDT), and investigates distribution of vehicle counts by model year as included in the EMFAC2017 and EMFAC2014.

4.2.2.2. POPULATION

Figure 4.2-1 compares EMFAC2017 and EMFAC2014 vehicle population for gasoline Passenger Cars (PCs). As shown, EMFAC2017 has higher vehicle population compared to EMFAC2014 for all calendar years after 2012, and shows 5 percent increase in the counts of PCs in calendar year 2016 relative to the forecasted vehicle population by EMFAC2014.

Figure 4.2-1: Comparison between EMFAC2017 and EMFAC 2014 PC gasoline vehicle population



As shown in Figure 4.2-2, EMFAC2014 predicted that there would be no growth in the counts of Light Duty Trucks (LDTs) over time while analysis of DMV data for EMFAC2017 shows that the number of gasoline light duty vehicles has been continuously growing since 2012. EMFAC2014 expected a total of approximately 9.8 million LDTs on the road since 2010, while the actual DMV vehicle counts processed for EMFAC2017 shows that the light duty vehicle population in calendar year 2016 was approximately 10 percent higher at 10.7 million vehicles.

Figure 4.2-2: Comparison between EMFAC2017 and EMFAC2014 LDT gasoline vehicle population

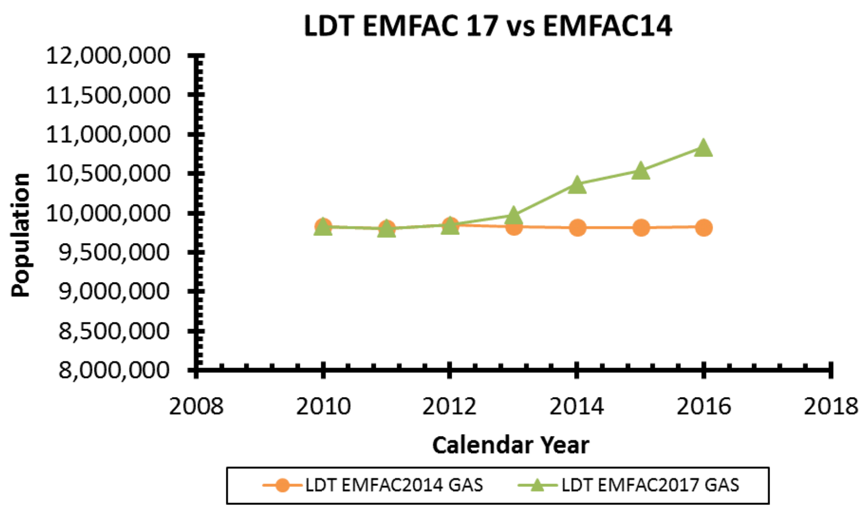
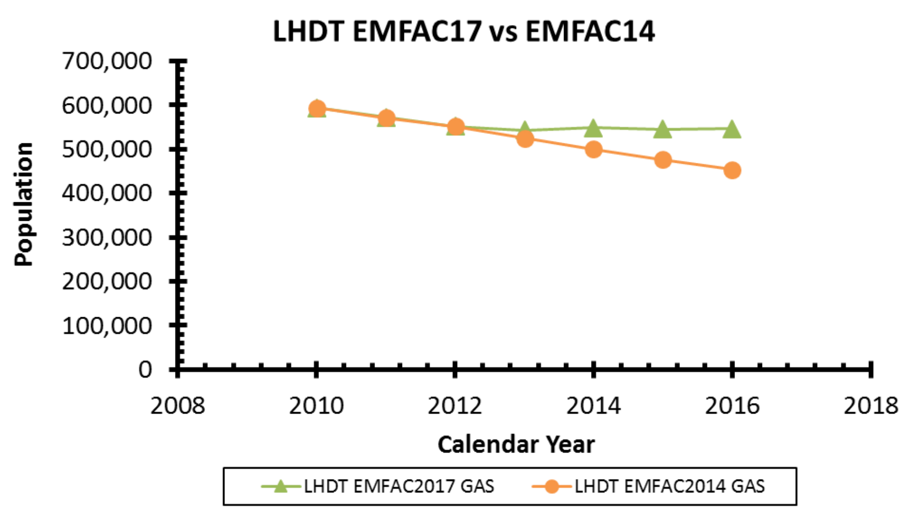


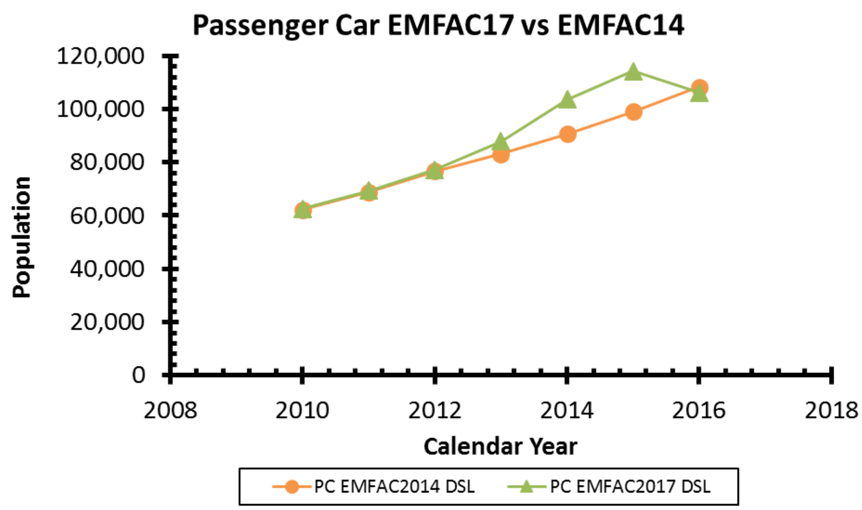
Figure 4.2-3 presents LHDT gasoline vehicle populations obtained for EMFAC2017 and EMFAC 2014. For gasoline LHDTs, EMFAC2017 predicted a continuous decline in the vehicle population over time, while EMFAC2014 forecasted that since 2012 the number of LHDT population on the road would be at the same level, at around approximately 550,000 vehicles.

Figure 4.2-3: Comparison between EMFAC2017 and EMFAC2014 LHDT gasoline vehicle population



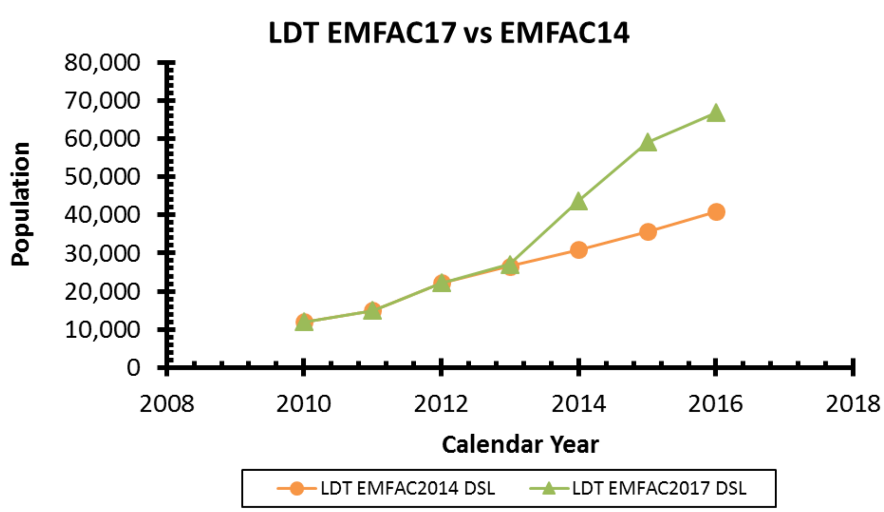
A comparison between EMFAC2017 and the projected EMFAC2014 vehicle populations is shown in Figure 4.2-4. Between calendar years 2013 and 2015 EMFAC2017 shows an increase in the number of diesel PCs relative to EMFAC2014. Due to a drop in EMFAC2017 diesel PCs population in 2015, both EMFAC2017 and EMFAC2014 agree on the number of diesel PCs.

Figure 4.2-4: Comparison between EMFAC2017 and EMFAC2014 PC diesel vehicle population



As shown in Figure 4.2-5, EMFAC2014 projected a slower growth rate for LDTs as compared to EMFAC2017 since calendar year 2013. EMFAC2014 expected a total of 40,000 diesel LDTs on the road while EMFAC2017 showed that in 2016 there was a total of approximately 65,000 diesel LDT vehicles on the road, or 62 percent higher.

Figure 4.2-5: Comparison between EMFAC2017 and EMFAC2014 LDT diesel vehicle population



For LHDT vehicles, as shown in Figure 4.2-6, EMFAC2014 predicted a continuous decline over time in the vehicle population, while EMFAC2017 shows a continuous growth since 2012. In calendar year 2016, the difference between the projected EMFAC2014 and EMFAC2017 is estimated to be approximately 16 percent. It is worth mentioning that the difference observed in the vehicle population before the year 2012 between EMFAC2014 and EMFAC2017 is not an error. The difference is due to a methodology change and the way LHDT vehicles are distributed among different GAIs. For the year 2012 and beyond, however, the difference is due to the forecasted EMFAC2014 and EMFAC2017 actual vehicles counts based on DMV registration data.

Figure 4.2-6: Comparison between EMFAC2017 and EMFAC2014 LHDT diesel vehicle population

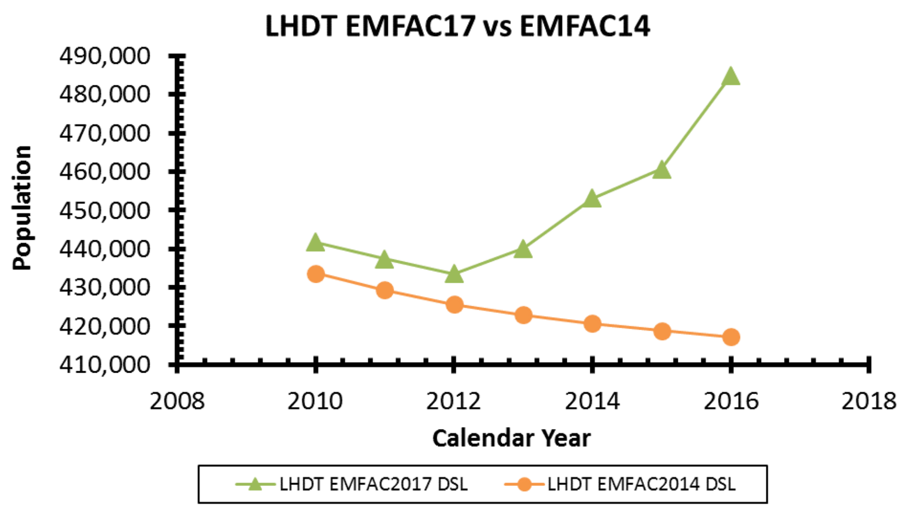


Figure 4.2-7 illustrates the observed EMFAC2017 electrical PC vehicle population versus the forecasted population of EMFAC2014. As shown, EMFAC2014 projected a slower growth rate for the population compared to EMFAC2017, hence, the difference between the two models grew to approximately 52 percent.

Figure 4.2-7: Comparison between EMFAC2017 and EMFAC2014 PC electric vehicle population

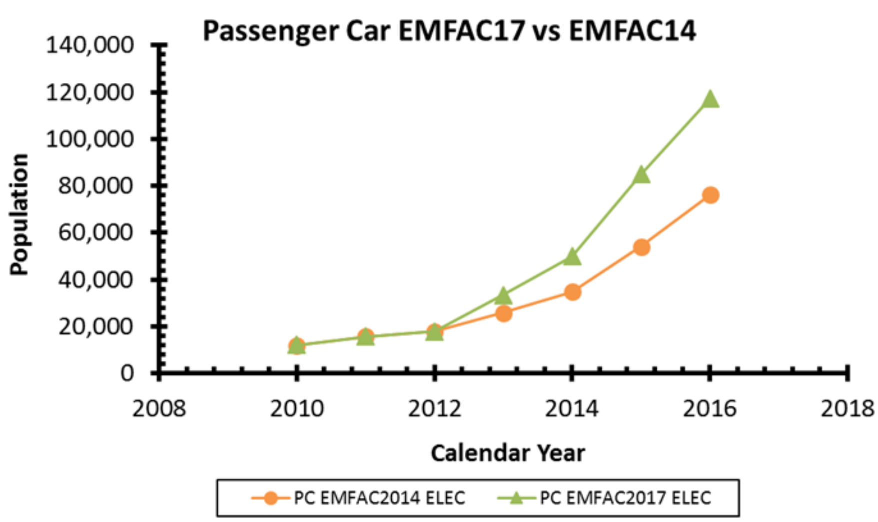
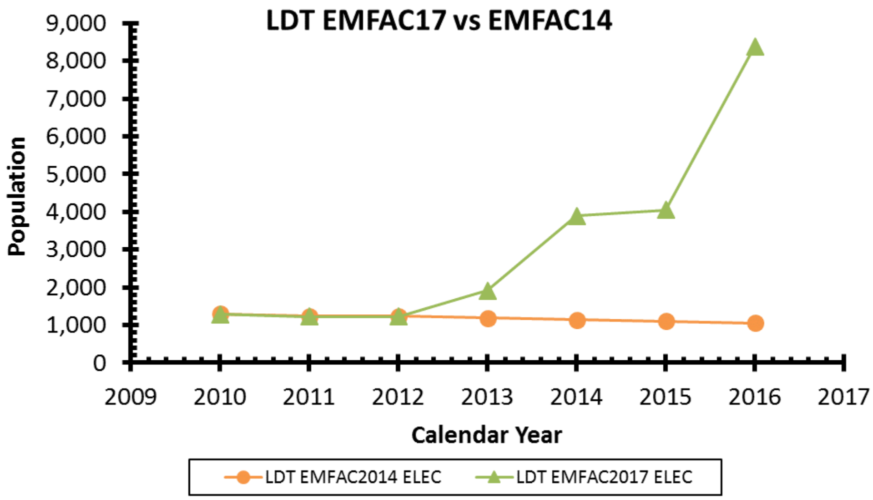


Figure 4.2-8 shows the population for electric LDT vehicles over time and reflects the EMFAC2014 assumption that the number of electric LDT vehicles would slightly decrease. EMFAC2017 and DMV registration data shows the number of electric LDTs gradually increased to over 8,000 vehicles in 2016 equal to approximately 800 percent increase relative to the base year vehicle population. According to EMFAC2014, the electric LDT vehicle population would decrease by approximately 20 percent compared to the base year.

Figure 4.2-8: Comparison between EMFAC2017 and EMFAC 2014 LDT electric vehicle population



4.2.2.3. NEW VEHICLE SALES

DMV registration does not provide any statistics on the new vehicle sales. Hence, the vehicle model year, available as a field, in DMV database is used to indirectly count how many new vehicles were sold over the course of past year and added to the fleet. Only vehicles with age less than or equal to zero are included. For example, in DMV2016B Cut, 2016 and 2015 model year vehicles are considered to be of age zero and age one, respectively.

In the continuation of this section, the change of vehicle population time is discussed. Note that the change in vehicle population is not only a function of new vehicle sales, but also vehicle migration and vehicles that get scrapped. Figure 4.2-9 shows the current trend in the new vehicle sales by model year for gasoline PCs and LDTs. The data is provided for EMFAC2017 and EMFAC2014. As can be seen, EMFAC2014 new vehicle sale projections are very consistent with EMFAC2017.

The same conclusion cannot be made for diesel PCs and LDT according to Figure 4.2-10. EMFAC2017 new vehicle sales surpassed EMFAC2014 projection between years 2012 and 2014. Starting in 2014, diesel PC new sales dropped by almost 85 percent lower than the projected sales estimated by EMFAC2014. Similarly, a drop in the population of diesel LDTs can be seen in 2015-2016. Our analysis shows that the diesel LDT vehicle population in 2016 is still approximately 30 percent above the level projected by EMFAC2014.

Figure 4.2-9: Comparison between EMFAC2017 and EMFAC2014 New Sales by Model Year for Gasoline PC and LDT Vehicle Classes

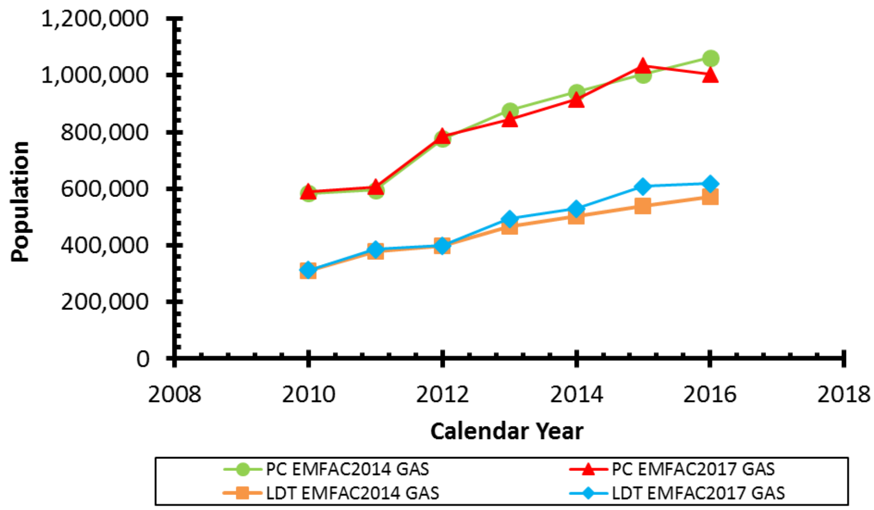
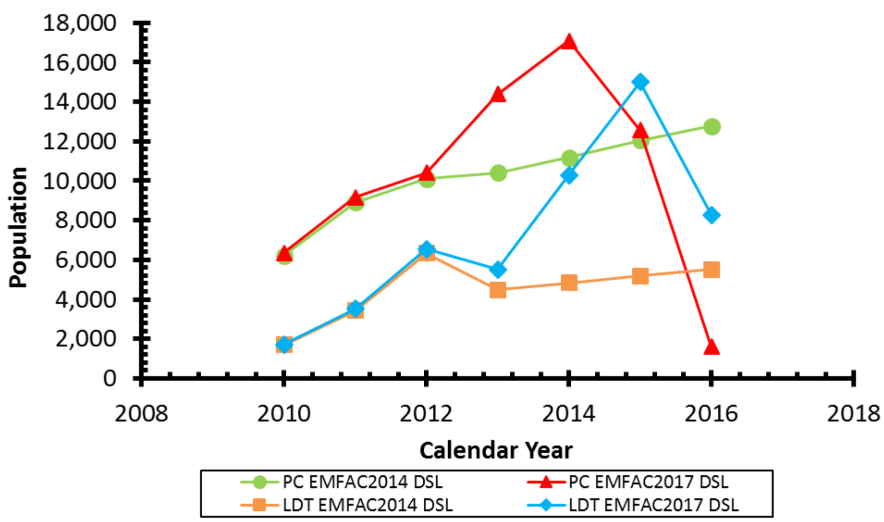


Figure 4.2-10: Comparison between EMFAC2017 and EMFAC2014 News Sales by Model Year for Diesel PC and LDT Vehicle Classes



Figures 4.2-11 through 4.2-13 show the distribution of vehicle population by model year for PCs, LDTs, and LHDTs and compare EMFAC2017 versus EMFAC2014. As shown for PCs in Figure 4.2-11, except for model years 2011 to 2016, EMFAC2017 and EMFAC2014 both use the same vehicle age distribution. The drop in the count of 2016 model year vehicles is due to the fact that the EMFAC2017 distribution only accounts for vehicles sales occurred during the months of January through October. Considering that more vehicles were sold, the PC vehicle population should be higher. For LDTs, as shown in Figure 4.2-12, EMFAC2017 uses a higher vehicle population for model years 1995 to 2006 and 2013 to 2015 when compared to the projected EMFAC2014 vehicle population. A similar analysis is done for LHDT vehicles and the results are shown in Figure 4.2-13. EMFAC2017 projected a lower vehicle count for 1990 to 2012 and 2015 to 2016 model year LHDT vehicles compared to EMFAC2017.

Figure 4.2-11: PC Vehicle Age Distribution by Vehicle Model Year for EMFAC2017 (DMV2016B) vs. EMFAC2014 (Projected) – all fuel types are included

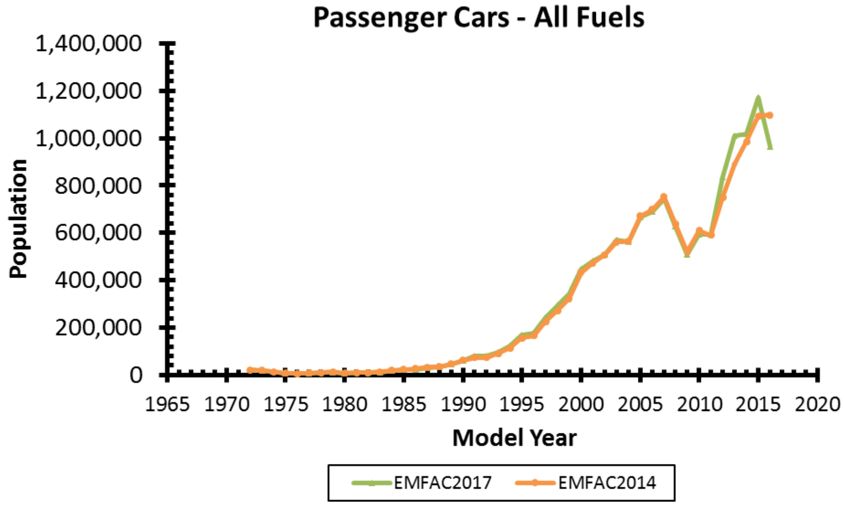


Figure 4.2-12: LDT Vehicle Age Distribution by Vehicle Model Year for EMFAC2017 (DMV2016B) vs. EMFAC2014 (Projected) – all fuel types are included

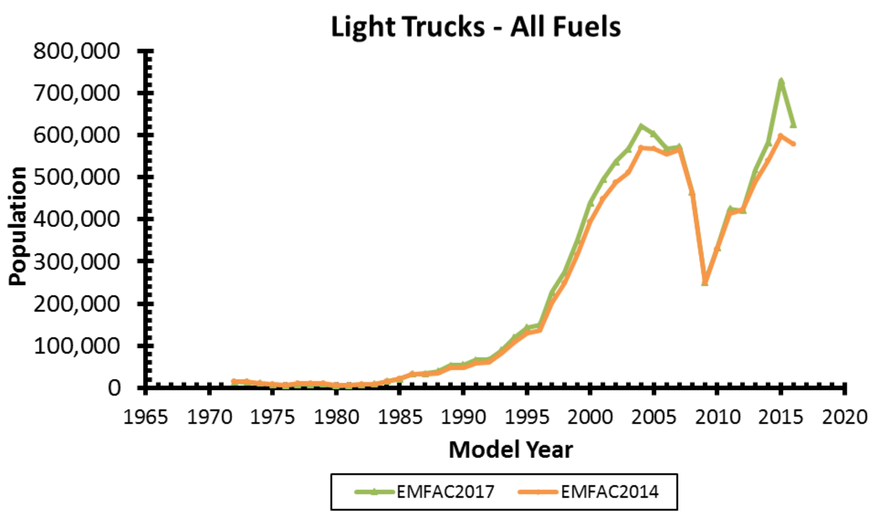
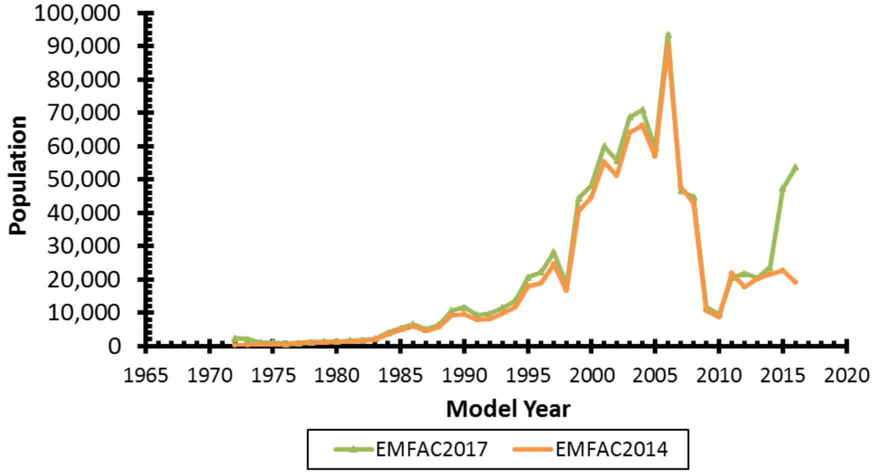


Figure 4.2-13: LHDT Vehicle Age Distribution by Vehicle Model Year for EMFAC2017 (DMV2016B) vs. EMFAC2014 (Projected) – all fuel types are included.



4.2.2.4. MAJOR DATA SOURCES

Major data sources used in the processing of DMV 2016 ‘A’ Cut and 2017 ‘B’ Cut are as follows.

- **Historical DMV Data.** This data comprises all the data used for development of EMFAC2014 including DMV 2012 ‘B’ Cut and older. It also includes DMV 2013 and newer datasets all the way up to DMV 2017 ‘A’ Cut.
- **Polk/IHS VINtelligence.** VINtelligence is a web service provided to CARB by Polk/IHS. The web service accepts VIN numbers as inputs and returns vehicle specifications associated with each VIN.
- **Ward’s Database.** Ward’s database is created by processing Ward’s Automotive Reports. This database provides information about different vehicle technologies and weight.
- **CARB Electronic Certification Database or Executive Orders.** This database is a compilation of CARB certifications by vehicle make, model, and model year. By querying this database, vehicle classes can be directly resolved.

4.2.2.5. CHANGES AND IMPROVEMENTS

The most important step in characterization of the fleet is to classify vehicles based on their weight class such that the assigned vehicle classes are consistent with CARB executive orders. Vehicle classification is initiated by inheriting vehicle classes from previously processed DMV data, or data from previous years. A record inherits a vehicle class from a previous year’s record if VIN numbers are the same. Vehicles that do not inherit a vehicle class are identified as vehicles that have appeared for the first time in the DMV database. To classify the newly appeared vehicles, historically vehicle weights from smog check reports were used. However, since the introduction of OBD based smog check program, there is no need to put the vehicles on dynamometers. Therefore, vehicle weights are no longer included in the smog check reports. As an alternative approach to obtaining vehicle weights, staff processed Ward’s Automotive Reports published for all the 2000 thru 2016 model year vehicles, and created a database. For each make, model, and model year vehicle using Ward's database, a vehicle weight and class were determined and assigned to each record. However, due to small variations in the weight of different vehicle trims, vehicle classes obtained using this approach did not completely match the classifications as specified in the CARB Executive Orders.

To make the vehicle classes consistent with the CARB Executive Orders and to correct for the noise introduced in the classification process due to the varying vehicle trim weights, staff decided to directly use the Executive Orders, and that required manually searching through approximately 29,000 scanned PDF file of the Executive Orders which was not feasible. Hence, staff used a fuzzy string algorithms such as Levenshtein distance, cosine similarity, and regular expressions to develop plug-ins for SQL software in order to be able to process a large number of vehicle records in significantly less amount of time.

For this version of EMFAC, staff also developed a VIN decoder program that can interface with Polk/IHS VINtelligence web service in order to obtain vehicle specifications for large number of VINs. For example, Figure 4.2-14 shows an example vehicle record. As shown on the left, according to DMV this vehicle is a Toyota and the model year is 2006. However, a lot of data fields are missing such as model name, series name, and fuel type. On the right, the VIN decoder has been used to obtain the missing information. The new VIN decoder enabled us to take a closer look at the fleet and determine the fleet composition in terms of advanced fuel technologies such as Battery Electric Vehicles (BEV), Hybrid Electric Vehicles (HEV), Plug-in Hybrid Electric Vehicles (PHEV), and Fuel Cell Electric Vehicles (FCEV). Historically, VIN patterns were used to identify whether or not a vehicle utilizes advanced fuel technologies.

Table 4.2-1: An example of DMV vehicle record. On the left, several fields are missing values. On the right, VINtelligence has been used to obtain the missing values for the record shown on the left.

DMV Data Field Names	Field Values Before Using VINtelligence	Field Values Before After Using VINtelligence
MAKE_DMV	TOYT	TOYT
MAKE_VINA	-	-
MAKE_NAME	-	TOYOTA
YEAR_MODEL	2006	2006
SERIES_CODE		HIGHLANDER
SERIES_NAME	-	-
MODEL_CODE	-	-
MODE_NAME	-	HYBRID
BODY_STYLE	UT	UT
MOTIVE_POWER	Q	Q
FUEL_TYPE	-	B
GVW_CODE	-	1
UNLADEN_WEIGHT	-	-
INCH3_DISP	-	201
TYPE_LIC_CODE	L0	L0
BODY_TYPE_MODEL	4D	4D
SOURCE	-	VINTELLIGENCE

4.2.2.6. SUMMARY OF FINDINGS

Major findings related to LD fleet characterization are listed below. Note that EMFAC2014, had a base year of 2012, hence, anything reported by EMFAC2014 for years 2012 and after are projected.

- Car/truck split has shifted toward more trucks in the fleet. In 2012, the split was 66 percent passenger cars and 34 percent trucks. In 2016, the split has moved to 62 percent passenger cars, and 38 percent trucks.
- Overall, EMFAC2017 has higher population for gasoline, diesel, and electric vehicles than projected by EMFAC2014.
- A significant drop is observed in the sales of new diesel PCs and LDTs based on data obtained from EMFAC2017.
- Electric LDT vehicle population grew significantly since 2012 according to EMFAC2017. EMFAC2014 forecasted a continuous decline in the population of this vehicle class.
- Relative to EMFAC2014, EMFAC2017 vehicle counts showed a significant increase in the sales of new LHDT vehicles in the year 2016.
- No significant change in the counts of light duty vehicles by model year is observed.
- There is no significant difference between EMFAC2017 and EMFAC2014 vehicle age distributions.

4.2.3. UPDATES TO HD FLEET CHARACTERIZATION

4.2.3.1. COMPOSITION OF HEAVY-DUTY FLEET OPERATING IN CALIFORNIA

This section is focused on the EMFAC2017 population trends for diesel and natural gas fueled heavy-duty (MHD and HHD) trucks and buses operating in California. Medium heavy-duty trucks have a gross vehicle weight rating of 14,001 to 33,000 pounds. Heavy heavy-duty trucks have a gross vehicle weight rating greater than 33,000 pounds. Bus fleet types include school buses, transit buses, motor coaches and other buses. EMFAC2017 and EMFAC2014 comparisons of the population counts, new vehicle sales and age distributions are provided below. EMFAC2014 had a base-year of 2012 while EMFAC2017 has a base-year of 2016.

4.2.3.2. INSTATE HEAVY-DUTY FLEET POPULATION

Figure 4.2-14 compares EMFAC2017 and EMFAC2014 vehicle population for heavy-duty instate trucks, those trucks that only operate within California. Please note that estimates from EMFAC2017 are based on the DMV vehicle registration data while EMFAC2014 estimates for years 2013 and onward are projected using forecasting method described in EMFAC2014 technical support documentation. As shown below, EMFAC2017 has a higher vehicle population compared to EMFAC2014 for all calendar years after 2012, and shows a 1.7 percent increase in the counts for calendar year 2016 relative to the forecasted vehicle population by EMFAC2014. EMFAC2014 had to make some assumptions about the economic recovery and the increased counts in the EMFAC2017 update are a positive economic sign.

Figure 4.2-14: Comparison between EMFAC2017 and EMFAC2014 Instate Heavy-Duty vehicle population.

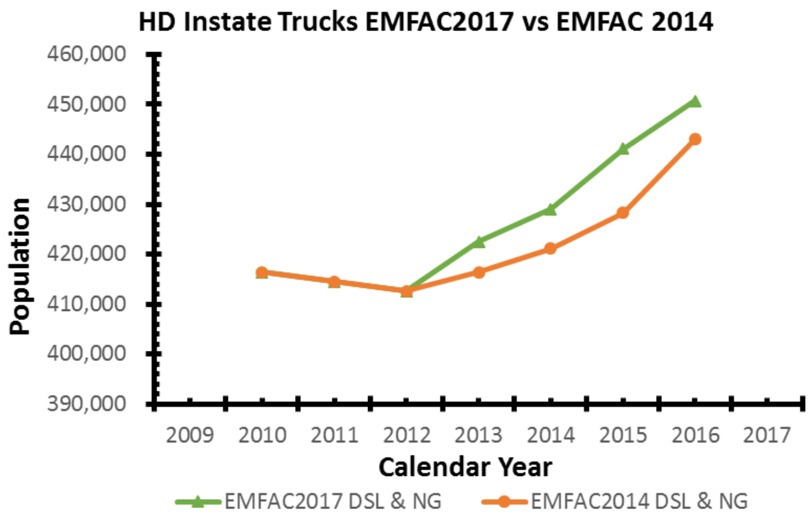


Figure 4.2-15 compares EMFAC2017 and EMFAC2014 new sales for heavy-duty instate trucks. New sales include all vehicles with chassis model years equal to or greater than the calendar year. For calendar years 2009 to 2012, EMFAC2017 reflects updated data processing results that show some differences from EMFAC2014. For calendar years 2013 to 2017, the new vehicles sales exceeded the EMFAC2014 forecasts due to the faster than anticipated economic recovery. Calendar year 2016 shows a 47.9 percent increase compared to the forecasted vehicle population by EMFAC2014.

Figure 4.2-15: Comparison between EMFAC2017 and EMFAC2014 Instate Heavy-Duty New Vehicle Sales.

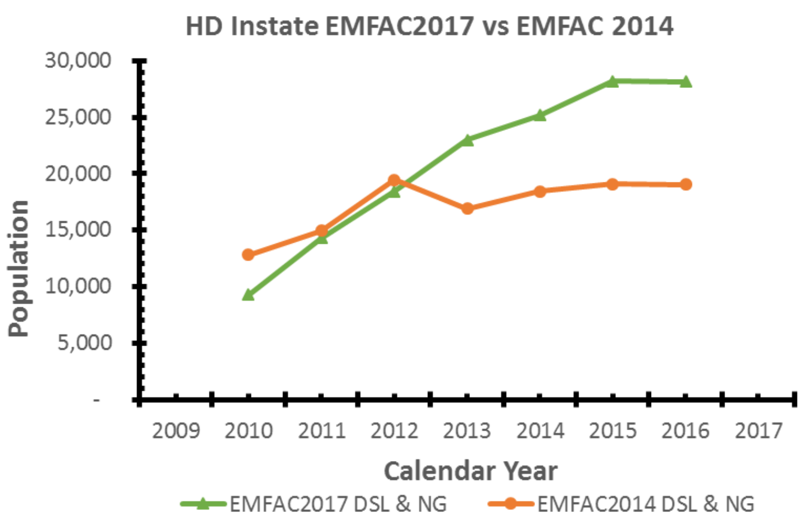
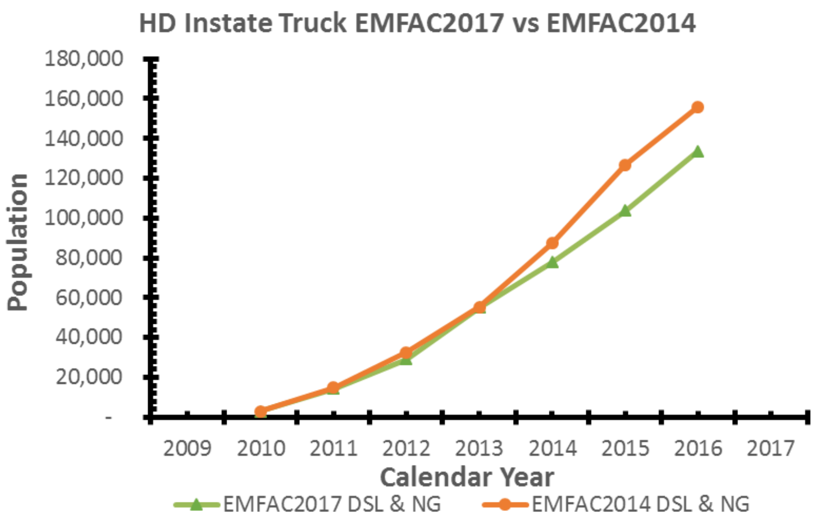


Figure 4.2-16 compares EMFAC2017 and EMFAC2014 counts of vehicles with a chassis model year of 2011 and greater which would be compliant with the Truck and Bus Rule model year 2010 engine standard requirements. For the majority of heavy-duty trucks, there is typically a one year lag in the chassis model year from the engine model year. These population counts

would include both new and used vehicle sales. Unlike the prior figures, the EMFAC2014 forecasted population exceeded the updated population for EMFAC2017. In calendar year 2016, EMFAC2017 showed a 14.4 percent decrease from the EMFAC2014 projection. For EMFAC2014, the Truck and Bus Rule assumptions anticipated a higher rate of model year 2010 engine compliant used vehicle sales. However, fleets have various options for achieving compliance, such as purchasing a model year 2007 engine standard vehicle with an original equipment manufacturer particulate filter, which would not need to be replaced with a 2010 engine standard vehicle until calendar year 2023. Thus, the penetration rate for chassis model year 2011+ vehicles has been increasing over time but at a slower rate than was forecasted in EMFAC2014.

Figure 4.2-16: Comparison between EMFAC2017 and EMFAC2014 MY2011+ Instate Heavy-Duty Vehicle Counts.



For the new base-year of 2016, EMFAC2017 reflects an average age of 11.3 for instate heavy-duty (MHD and HHD) vehicles. EMFAC2014 used calendar year 2012 as the base year also with an average age of 11.3 Figure 4.2-17 provides a comparison of the age distributions of the calendar year 2016 EMFAC2017 base year with the calendar year 2012 EMFAC2014 base year. Note that on all the following age distribution charts, population counts for 1972 and older are shown as model year 1972.

Figure 4.2-17: Comparison between EMFAC2017 and EMFAC2014 Instate Heavy-Duty Base Year Age Distribution.

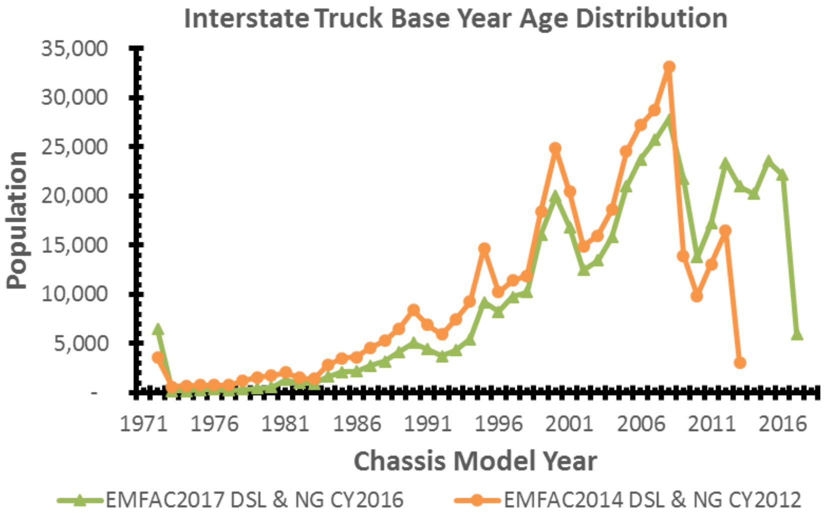
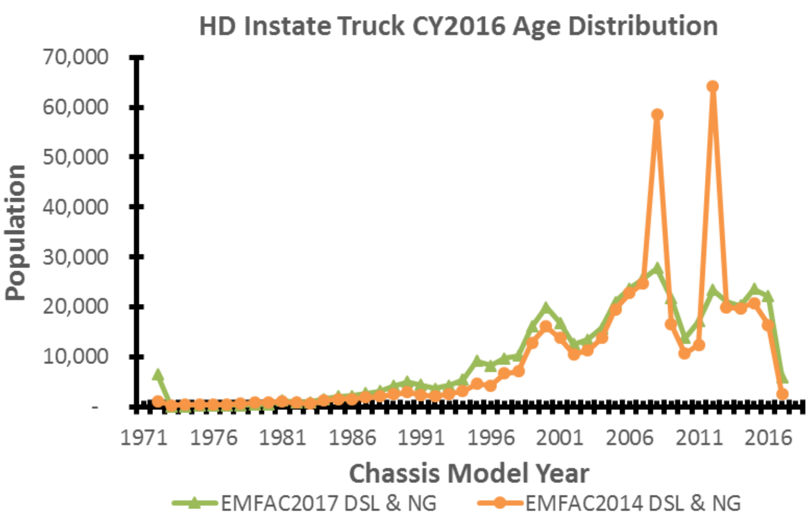


Figure 4.2-18 compares the EMFAC2014 projected age distribution for calendar year 2016 with the updated EMFAC2017 base year of calendar year 2016. As already noted above, assumptions had to be made in EMFAC2014 regarding Truck and Bus Rule compliance path options. These assumptions over-estimated the number of MY2008 and MY2012 truck replacements. Modeling assumptions have to assume a conservative path to compliance based on Best Available Control Technology (BACT) schedules. For example, a fleet may always purchase new vehicles but since they could comply with an older, used vehicle replacement, the model will make that more conservative assumption. Additionally, fleets have alternative compliance options (such as the fleet phase-in options) which they can utilize in lieu of meeting BACT schedules.

Figure 4.2-18: Comparison between EMFAC2017 and EMFAC2014 Instate Heavy-Duty Age Distribution.



Port trucks had to meet the drayage rule that required MY2007 or newer engines by the beginning of calendar year 2014 which lowered the average age of this fleet group. The Port Truck population in the calendar year 2012 base year for EMFAC2014 had an average age of 4.8. After all the drayage rule requirements were met, no further vehicle replacements were required so the average age increased to 5.6 in the new base year for calendar year 2016. This is close to the projected average age of 5.3 for calendar year 2016 in EMFAC2014. Figure 4.2-19 shows the comparison of the updated EMFAC2017 calendar year 2016 base year with the EMFAC2014 projected population for calendar year 2016. Older chassis model years would reflect engine repowers. It should be noted that Port trucks will need to meet the 2010 engine standard requirement in the future as required by the Truck and Bus rule.

Figure 4.2-19: Comparison between EMFAC2017 and EMFAC2014 Heavy Heavy-Duty Port Truck Age Distribution.

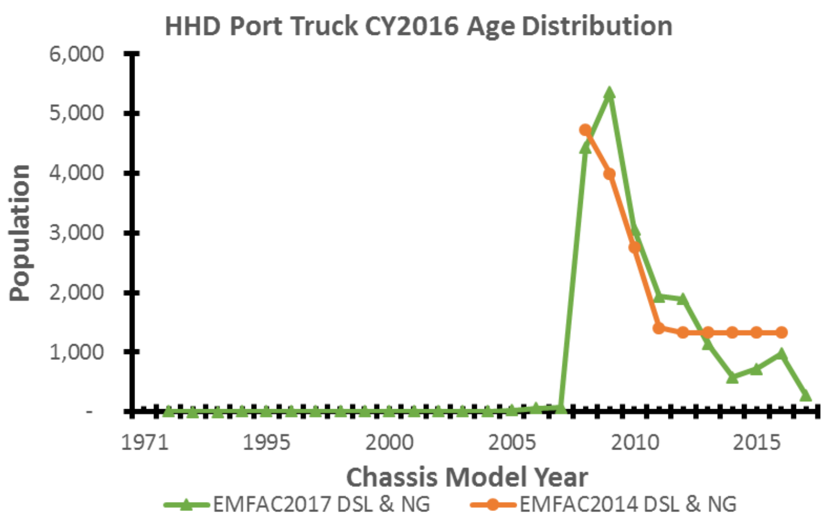
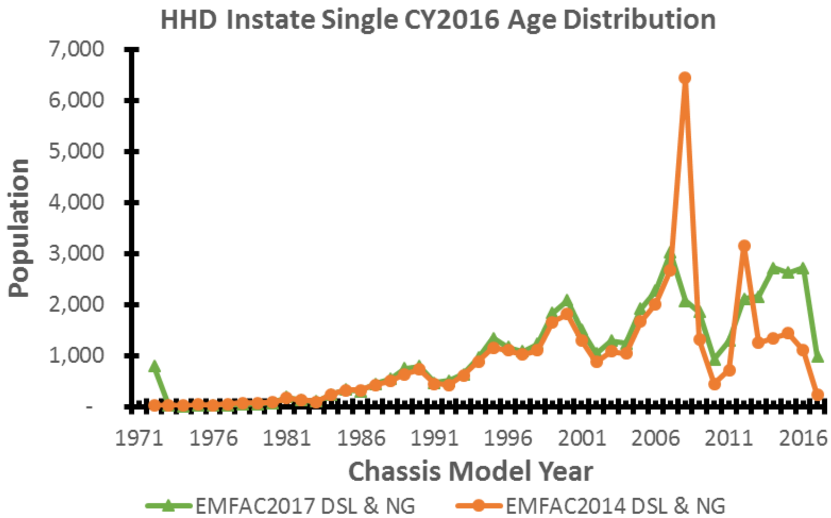


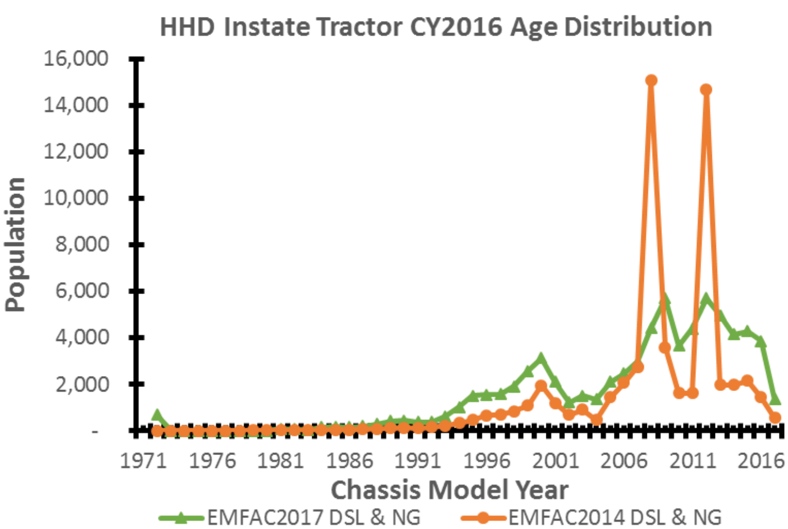
Figure 4.2-20 displays a comparison of the updated EMFAC2017 calendar year 2016 base year with the EMFAC2014 projected population for calendar year 2016 for heavy heavy-duty instate singles (excluding public and utility trucks, and agricultural (Ag) vehicles claiming Truck and Bus exemptions).

Figure 4.2-20: Comparison between EMFAC2017 and EMFAC2014 Heavy Heavy-Duty Instate Single Age Distribution.



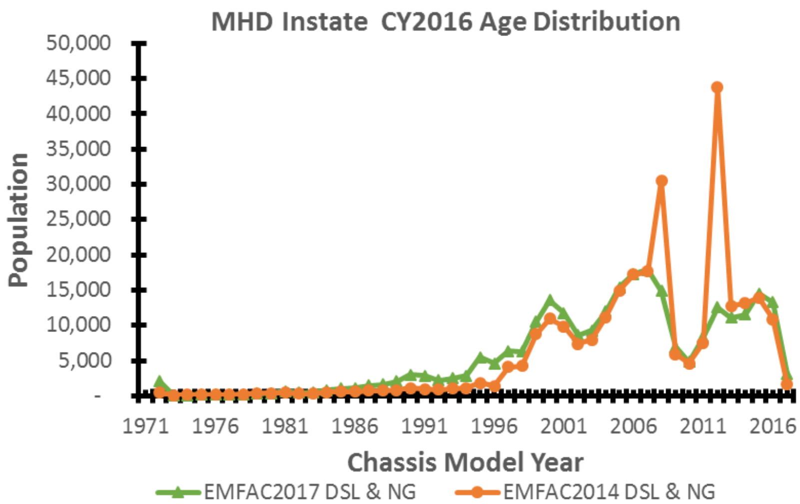
For HHD instate singles, the EMFAC2014 base year of calendar year 2012 had an average age of 13.1 which has decreased to 12.0 in the updated EMFAC2017 base year of calendar year 2016. This is similar to the 12.4 average age that EMFAC2014 projected for year 2016. A comparison of the updated EMFAC2017 calendar year 2016 base year with the EMFAC2014 projected population for calendar year 2016 for heavy heavy-duty instate tractors (excluding solid waste collection vehicles, public and utility trucks, and Ag vehicles claiming Truck and Bus exemptions) is shown in Figure 4.2-21.

Figure 4.2-21: Comparison between EMFAC2017 and EMFAC2014 Heavy Heavy-Duty Instate Tractor Age Distribution.



The EMFAC2014 base year of calendar year 2012 had an average age of 10.7 which has decreased to 9.5 in the updated EMFAC2017 base year of calendar year 2016. This is higher than the 7.9 average age that EMFAC2014 projected for calendar year 2016. As discussed above and seen in the chart, Truck and Bus compliance modeling assumptions over-estimated the number of MY2008 and MY2012 truck replacements. Figure 4.2-22 shows similar results for the medium heavy-duty instate vehicles. The EMFAC2014 base year of calendar year 2012 had an average age of 10.8, which has decreased to 11.3 in the updated EMFAC2017 base year of 2016. This is higher than the 9.1 average age that EMFAC2014 projected for year 2016.

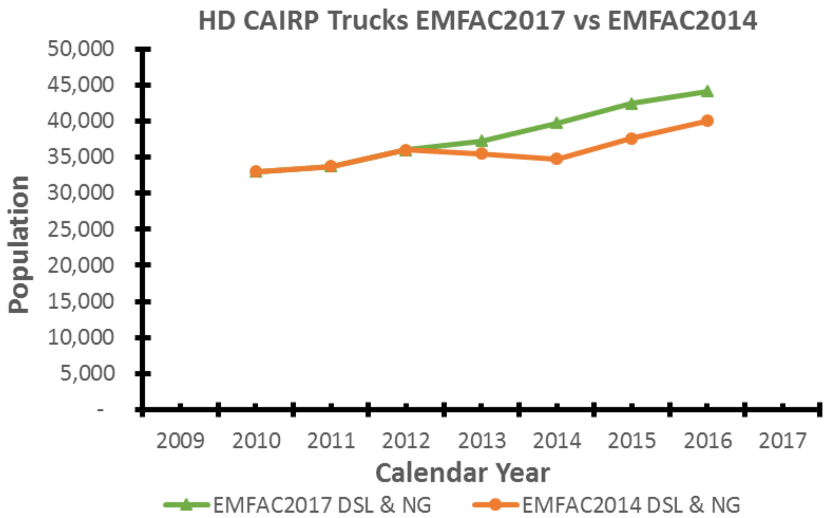
Figure 4.2-22: Comparison between EMFAC2017 and EMFAC2014 Medium Heavy-Duty Instate Age Distribution.



4.2.3.3. CALIFORNIA INTERSTATE (CAIRP) HEAVY-DUTY FLEET POPULATION

Figure 4.2-23 compares EMFAC2017 and EMFAC2014 vehicle population for heavy-duty Interstate trucks that report into the International Registration Plan (CAIRP) that designate the fleet's base jurisdiction as California. These trucks are authorized to operate within California and within other states or provinces. As shown below, EMFAC2017 has a higher vehicle population compared to EMFAC2014 for all calendar years after 2012, and shows a 10.3 percent increase in the counts for calendar year 2016 relative to the forecasted vehicle population by EMFAC2014, again reflecting the positive economic recovery.

Figure 4.2-23: Comparison between EMFAC2017 and EMFAC2014 CAIRP Heavy-Duty vehicle population.



For the heavy heavy-duty CAIRP, the calendar year 2012 EMFAC2014 base-year had an average age of 6.3, which has decreased to 5.8 in the calendar year 2016 updated base-year for EMFAC2017. The HHD CAIRP updated population for EMFAC2017 has more than doubled over the EMFAC2014 base-year counts, with over 55 percent meeting the 2010 engine standard (Figure 4.2-24).

Figure 4.2-24: Comparison between EMFAC2017 and EMFAC2014 Heavy Heavy-Duty CAIRP Age Distribution.

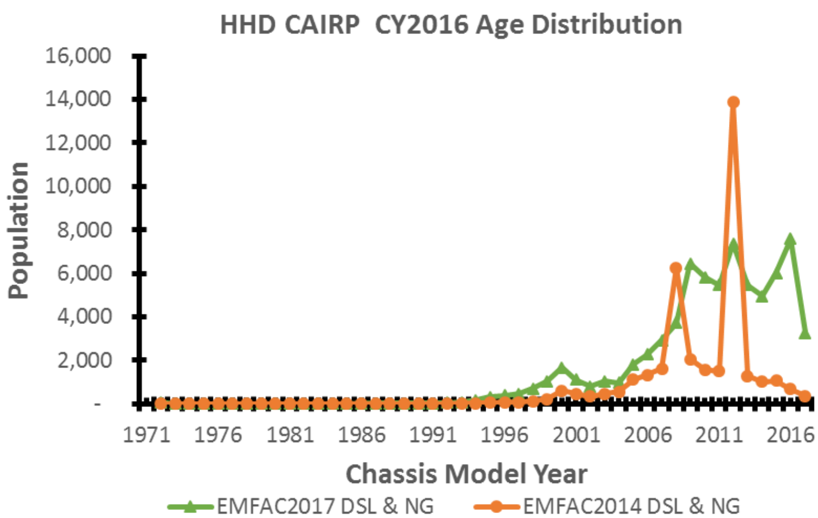
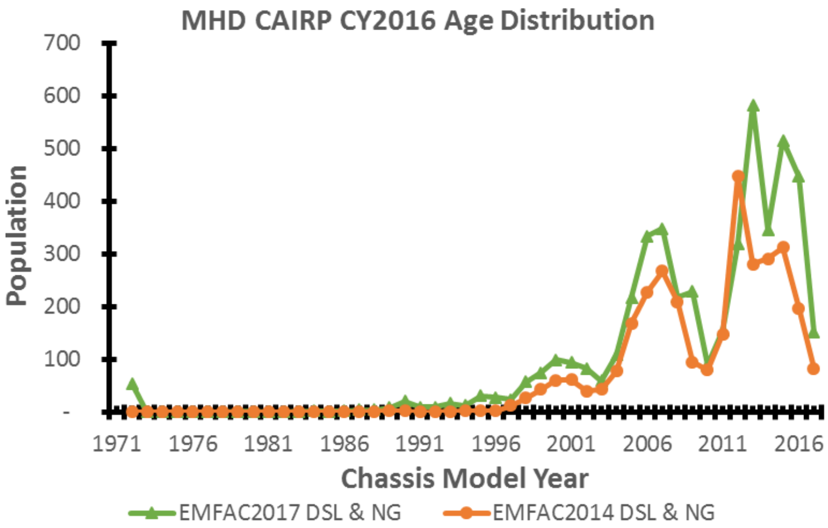


Figure 4.2-25 displays a comparison of the updated EMFAC2017 calendar year 2016 base year with the EMFAC2014 projected population for calendar year 2016 for MHD CAIRP. The EMFAC2014 base year of calendar year 2012 had an average age of 7.5, which has decreased to 6.8 in the updated EMFAC2017 base year of calendar year 2016. This is a slightly higher than the 6.1 average age that EMFAC2014 projected for calendar year 2016.

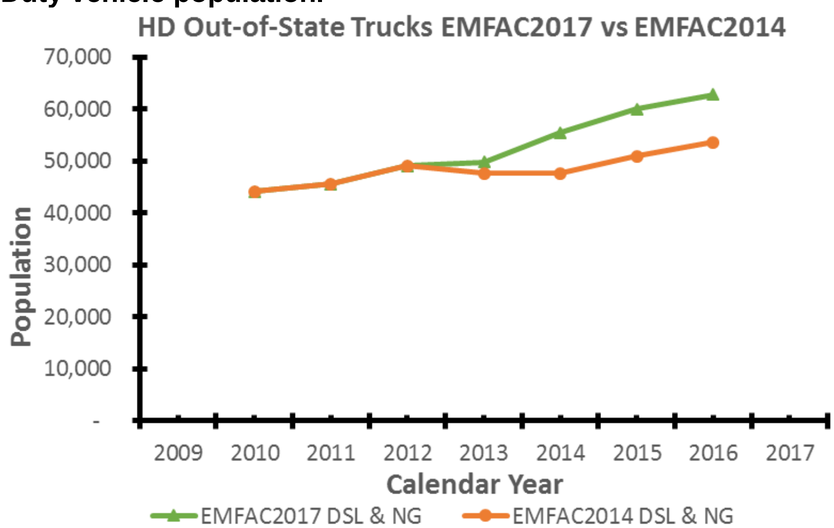
Figure 4.2-25: Comparison between EMFAC2017 and EMFAC2014 Medium Heavy-Duty CAIRP Age Distribution.



4.2.3.4. OUT OF STATE HEAVY-DUTY FLEET POPULATION

Figure 4.2-26 shows the typical daily count estimates for out-of-state IRP heavy-duty trucks, which have base jurisdictions outside of California but are authorized to travel within California. The majority of these vehicles are heavy heavy-duty but also includes smaller numbers of medium heavy-duty vehicles.

Figure 4.2-26: Comparison between EMFAC2017 and EMFAC2014 Out-of-State IRP Heavy-Duty vehicle population.

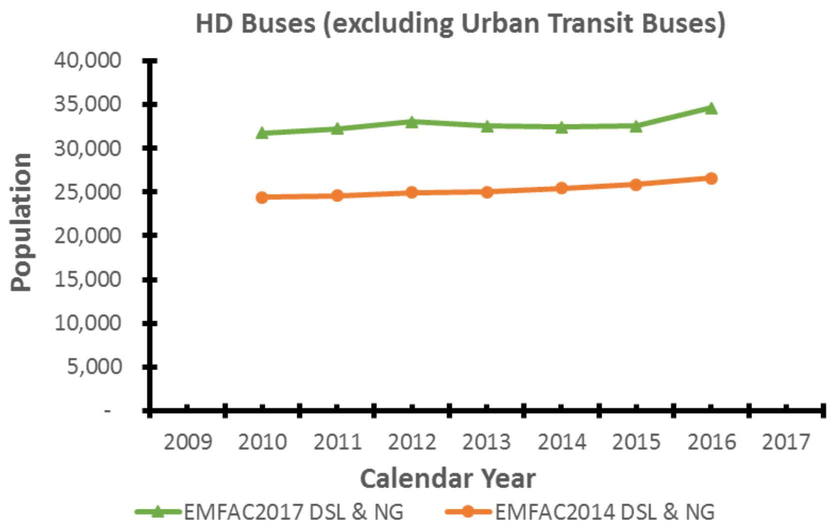


The annual counts of vehicles from out of state that operate in California would be higher. Fleets that are authorized to operate in California may send all or none of their vehicles to California, and report mileage information per fleet and not per vehicle. EMFAC focuses more heavily on the vehicle miles traveled within California than these population counts. Similar to the California based trucks, the out-of-state truck counts also increased at a rate higher than was forecasted in EMFAC2014. In calendar year 2016, the EMFAC2017 counts exceeded the EMFAC2014 projection by 16.9 percent.

4.2.3.5. BUS FLEET POPULATION

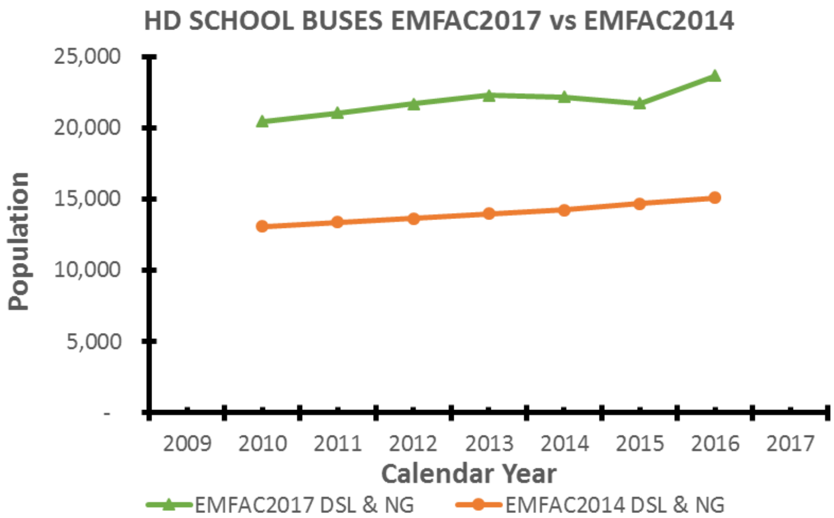
As was noted above, bus fleet types include school buses, transit buses, motor coaches and other buses. The most significant change for EMFAC2017 as compared to EMFAC2014 is the development of a separate module for the urban transit bus inventory. Figure 4.2-27 displays the updated heavy-duty bus population for EMFAC2017 with a comparison to EMFAC2014 for the new base-year of calendar year 2016.

Figure 4.2-27: Comparison between EMFAC2017 and EMFAC2014 Heavy-Duty Bus vehicle population (excluding Urban Transit Buses).



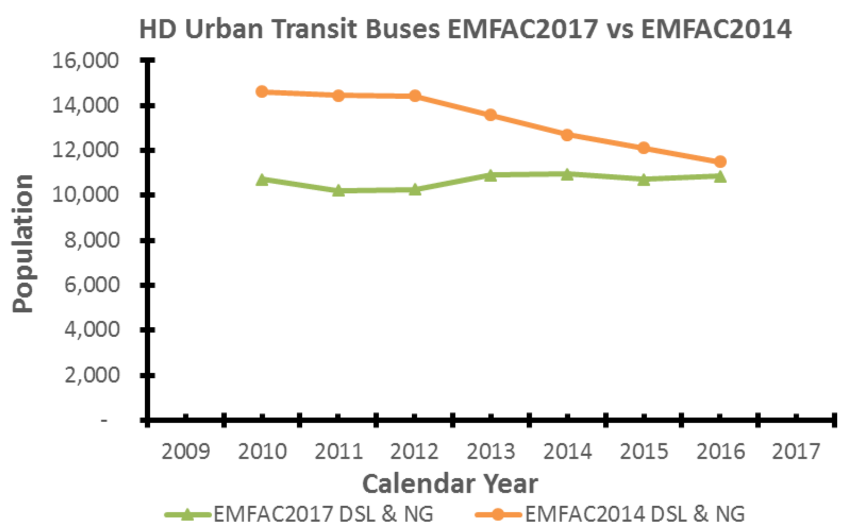
To improve the accuracy of the school bus inventory, as school buses can be difficult to identify as such in DMV, EMFAC2017 made use of California Highway Patrol inspection reports to flag currently operating vehicles in DMV. The flagged DMV school bus population was then scaled up to reflect the CHP list of total vehicle counts. The increased vehicle population for EMFAC2017 over EMFAC2014 as seen in Figure 4.2-28 reflects the improved identification of school buses. The scaling process might have resulted in some buses that are less than 14,000 pounds being presented as heavy-duty buses.

Figure 4.2-28: Comparison between EMFAC2017 and EMFAC2014 Heavy-Duty School Bus vehicle population.



New for EMFAC2017 is a transit bus module to more accurately characterize the transit bus fleet. As will be discussed in the next section on data sources, the National Transit Database has been used to update EMFAC2017. The updated lower counts for EMFAC2017 as compared to EMFAC2014, as presented in Figure 4.2-29, better represent Urban Transit Buses actually operating on the road.

Figure 4.2-29: Comparison between EMFAC2017 and EMFAC2014 Heavy-Duty Urban Transit Bus vehicle population.



4.2.3.6. MAJOR DATA SOURCES FOR UPDATE

Major data sources used to process the heavy duty vehicle inventory are as follows.

Processed DMV data. As discussed in the light duty vehicle section, DMV data sets were processed using additional inputs from various data sources to provide updated vehicle information for vehicles registered in California. DMV data field values are used to designate utility and public fleet vehicles, and to identify tractors and solid waste collection vehicles. After identifying all other fleet types using all of the various data sources, the remaining trucks are designated as instate single trucks and the remaining buses are designated as all other buses.

International Registration Plan (IRP) Data. IRP Clearinghouse data is another primary data source for heavy-duty vehicle updates. Vehicles already registered in California can be identified as interstate trucks (CA IRP fleet) or buses (motor coach fleet). In addition, for out-of-state vehicles in states and provinces that report to the IRP Clearinghouse, updates can be made using vehicle characteristics for fleets with travel to California. Out-of-state fleets report into IRP their annual mileage to California at a fleet level, and not per individual vehicle. Since out-of-state fleets may send many or none of their fleet's individual trucks to travel into California, it is more important to estimate the VMT travel in California than to estimate counts of unique out-of-state vehicles, which cannot be determined accurately. Using calendar years 2008 through 2015 International Fuel Tax Agreement (IFTA) mileage data and assuming T7 (HHDT) vehicles represented 95 percent of all the reported VMT and T6 (MHDT) vehicles represented 5 percent (based on past studies), the historical ratio of VMT for out-of-state trucks as compared to VMT by CA IRP trucks was updated to 1.22 for T7 Non-Neighboring Out-of-state truck (NNOOS) and to 0.393 for T7 Neighboring Out-of-state truck (NOOS) for EMFAC2017. After VMT was calculated for T6 OOS, T7 NNOOS and T7 NOOS, population were back-calculated with the use of accrual schedules.

TRUCRS[16] data for diesel Truck and Bus Rule. Data was extracted from the TRUCRS database to update the heavy-duty inventory as needed for fleets utilizing flexible compliance options to meet Truck and Bus Rule requirements. In EMFAC2017, Ag Fleet vehicle counts only reflect vehicles using specific agricultural exemptions for compliance purposes.

List of VINs from Major Ports. For EMFAC2017, the Port of Los Angeles/Long Beach and the Port of Oakland provided lists of VINs for vehicles that actually visited the ports to directly flag these vehicles as port trucks. This provided us the capability to accurately estimate population of class 8 trucks that visit ports frequently.

List of VINs from California Highway Patrol (CHP) School Bus Inspections[17]. The CHP now provides data on School Buses that receive safety inspections that are required by law. This dataset significantly improved the population of school buses in EMFAC.

National Transit Database (NTD) data. The National Transit Database[18] was used to characterize the transit fleet for EMFAC2017 in the newly developed transit bus module.

4.2.3.7. CHANGES AND IMPROVEMENTS

This section describes the primary changes and improvements to the heavy-duty fleet inventory in EMFAC2017.

[16] https://www.arb.ca.gov/msprog/onrdiesel/reportinginfo.htm
[17] https://www.chp.ca.gov/Programs-Services/Programs/School-Bus-Program
[18] https://www.transit.dot.gov/ntd

Port Trucks. In EMFAC2014, port truck fleet populations were estimated using data from a 2005 staff report, which was then adjusted each calendar year by the TEU shipping container growth rate changes as compared to 2005. As already noted above, for EMFAC2017, the actual VINs from the large ports were provided to be able to flag DMV vehicles that actually operated at those ports, increasing the accuracy of the instate port truck fleet. It should be noted that interstate vehicles that travel to the ports are not included in the port truck fleet as they are designated to be CA IRP or out-of-state fleets.

School Buses. In EMFAC2014, the DMV school bus designations were used but DMV does not require regular updates for school bus fleets. For EMFAC2017, as referred to above, the CHP is now providing periodic VIN lists from required school bus inspections, which allows for directly flagging these vehicles as school buses. The CHP data provides a method for more accurate counts of school buses actually operating on the road in California.

New transit bus module. EMFAC2014 identified transit buses in DMV using addresses and as exempt vehicles, however, DMV data is not regularly updated for transit fleets. Thus, a more current data source was desirable. As noted above, for EMFAC2017 the National Transit Database is being used to characterize the transit fleet in the newly developed transit bus module. This database has California specific data for the years of 2000 to 2015. All transit agencies must report in order to receive federal grants, which is highly desirable. The NTD data has been found to provide more accurate and detailed information, which allows for better identification of zero emission buses and the types of buses (such as articulated and cutaway bus types). The additional detail increases the ability for modeling transit buses more accurately in EMFAC. The most current year's data that was available for updating EMFAC2017 was 2015, so unlike most fleets with a base-year of 2016, the new urban transit bus module uses a base-year of 2015.

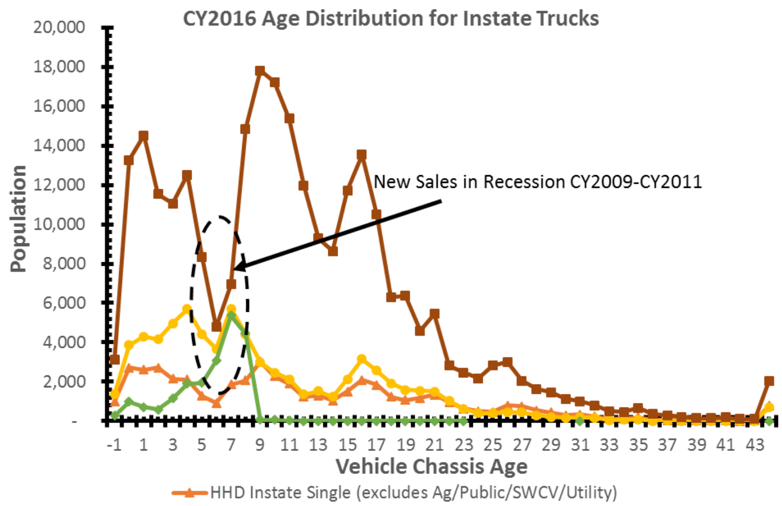
4.2.3.8. MAJOR FINDINGS

This section discusses the major findings for the heavy-duty vehicles when comparing EMFAC2017 updated results to EMFAC2014.

Increased Population. Overall, when comparing the EMFAC2017 updated population for calendar years 2013 through 2016 to the projected population in EMFAC2014, there is now a higher heavy-duty vehicle population reflecting the post-recession economic recovery which exceeded the projected estimates.

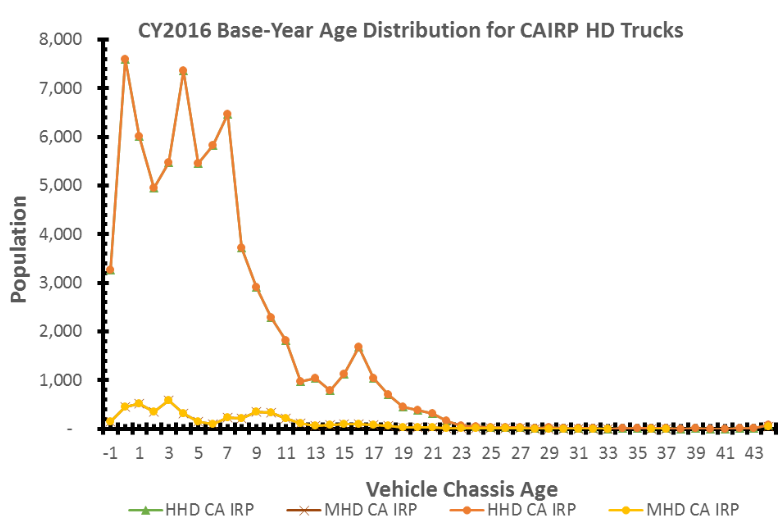
Instate Trucks. There has been an increased penetration of Truck and Bus compliant MY2010 standard engine heavy-duty vehicles which represent approximately 30 percent of the instate HD trucks in calendar year 2016. These would be the chassis age 5 or newer and potentially some of the age 6 as shown in Figure 4.2-30. The high population counts around age 9 reflect fleets purchasing higher volumes of the 2007 standard engine vehicles with original equipment manufacturer (OEM) particulate matter (PM) filters to meet Truck and Bus Rule Requirements that allow them to remain in fleets until calendar year 2023. Ages 5 to 7 show the slowed vehicle sales during the recessionary period except for port trucks which had to meet drayage rule requirements. The vast majority of Instate trucks in the fleets displayed will need to meet the MY2010 standard engine heavy-duty requirement by calendar year 2023.

Figure 4.2-30: Calendar year 2016 Base-Year Age Distribution for Instate HD Trucks



Interstate Trucks. For the CA IRP trucks, the MY2010 standard engine heavy-duty vehicles represent approximately 56 percent of the instate HHD and 53 percent of the MHD trucks in calendar year 2016. Figure 4.2-31 displays the CA IRP fleet age distributions. The fraction of MY2010 standard engines increases to over 66 percent for the NNOOS fleet vehicles as reported into IRP for calendar year 2016. However, as discussed above, EMFAC2017 models the out-of-state vehicles based on VMT, as it is not certain which of the out-of-state fleet vehicles are actually being sent into California. Typically, older vehicles travel closer to a fleet's home base so the percentage of compliant out-of-state trucks operating in California is expected to be higher. Out-of-state fleets must comply with Truck & Bus rule requirements for the vehicles that travel into California and will be subject to CARB enforcement programs.

Figure 4.2-31: Calendar year 2016 Base-Year Age Distribution for CAIRP HD Trucks



School buses. The population of school buses has increased in EMFAC2017 as compared to EMFAC2014 after using the new CHP school inspection list of VINs to flag school buses in the DMV data set.

Urban Transit Buses. The new transit bus module that is now using NTD data to characterize the urban transit bus fleet results in a decreased population in EMFAC2017 as compared to EMFAC2014.

4.2.3.9. UPDATES FOR DIESEL IN-USE FLEET RULES[19]

EMFAC2014 incorporated regulatory changes for diesel In-Use Fleet Rules using assumptions regarding the most likely compliance path options that might be selected. For EMFAC2017, compliance assumptions had to be updated starting with the new calendar year 2016 base-year inventory and applying updated compliance assumptions as appropriate.

4.2.3.9.1. TRUCK AND BUS RULE COMPLIANCE ASSUMPTIONS

Compliance assumptions for EMFAC2017 reflect the changes in actual inventory with the new calendar year 2016 base-year and updated compliance path options for fleets to meet the diesel In-Use Fleet Rules. The following sections present the updated Retrofit/Replacement assumptions. A delay in the engine technology standards as compared to the chassis model year has been assumed for modeling purposes. Thus, a chassis model year of 2008 (MY2008) and newer are assumed to have OEM DPFs and MY2012 and newer vehicles are assumed to meet 2010 engine standards. EMFAC2014 assumed 100 percent compliance with the Truck and Bus Rule. Based on more recent information, EMFAC2017 assumptions do not assume 100 percent compliance each year, however, it is assumed that full compliance will be achieved by calendar year 2023.

The tables list the “Action”, either retrofitting with diesel particulate filters (DPF), or a replacement of an older vehicle with a newer vehicle (turnover). The “DPF” in the “Action” column designates a retrofit requirement for a pre-2008 vehicle not equipped with OEM filters. The numbers (such as 2008, 2012, 2013, etc.) in the “Action” column designate the model year of the replacement vehicles. EMFAC2014 assumptions began for January 1, 2014. EMFAC2014 assumptions begin for January 1, 2017 since the inventory has been updated through calendar year 2016.

4.2.3.9.1.1. LOW USE VEHICLE[20]

A low-use vehicle is one that operates less than 1,000 miles per calendar year within California’s borders. Until January 1, 2020, low-use vehicles also include vehicles that travel less than 5,000 total miles per calendar year. To qualify for this exemption, vehicles must report

[19] https://www.arb.ca.gov/msprog/truckstop/tb/truckbus.htm
[20] https://www.arb.ca.gov/msprog/onrdiesel/documents/fsLowuse.pdf

annual odometer readings into TRUCRS and maintain records, which are subject to CARB audits. EMFAC2017 assumes that all pre-2012 low use vehicles (with less than 5,000 miles per year) would be replaced with MY2012 vehicles by January 1, 2020.

4.2.3.9.1.2. WORK TRUCK PHASE-IN OPTION[21]

This option allows owners that meet minimum PM filter requirements each year, from 2014 to 2018, to defer compliance for trucks in the fleet that meet the work trucks eligibility criteria and travel less than 20,000 miles per year and exceed the above low-use vehicle thresholds. For EMFAC2017, the compliance assumptions were modeled as illustrated in Table 4.2-2. Pre-2008 MY vehicles that were not retrofit by 2017 are assumed to have 50 percent of the vehicles replaced with MY2012 vehicles by 2017 and 100 percent by 2018. The remaining work trucks with retrofit or OEM particulate filters are assumed to be replaced with MY2013 vehicles by 2023.

Table 4.2-2. Replacement Assumptions for Work Truck Phase-In Option

By Jan 1	Vehicle Model Year	Fleet Action (Turnover to)
2017	Remaining Pre-2008 Not DPF Retrofitted	50% 2008
2018	Remaining Pre-2008 Not DPF Retrofitted	100% 2008
2023	DPF Retrofitted Prior to 1/1/2017	2013
2023	2008-2011	2013

4.2.3.9.1.3. SPECIALTY AND LIMITED MILEAGE AGRICULTURAL TRUCK PROVISIONS[22]

Agricultural truck provisions provide extensions for vehicles that applied in TRUCRS as having eligible specialty equipment or that operate within limited mileage thresholds. From January 1, 2017 to January 1, 2020 the mileage limit is 15,000 miles per year. From January 1, 2020 to January 1, 2023 the mileage limit is 10,000 miles per year. Limited mileage vehicles above 10,000 miles/year and less than 15,000 miles/year are assumed to have 25 percent of the vehicles replaced with MY2012 vehicles by 2017, 50 percent by 2020 and 100 percent by 2023. By 2023, all of the specialty equipment and the limited mileage vehicles of less than 10,000 miles/year are also assumed to be replaced with 2012 MY trucks.

Table 4.2-3. Replacement Assumptions for Ag Truck

By Jan 1	Ag Provision	Vehicle Model Year	Fleet Action (Turnover to)
2017	Limited – Mileage (>10,000 & <=15,000)	Pre-2008	25% 2012
2020	Limited – Mileage (>10,000 & <=15,000	Pre-2008	50% 2012
2023	All Ag Provisions	Pre-2012	100% 2012

[21] https://www.arb.ca.gov/msprog/onrdiesel/documents/faqconstructiontrucks.pdf
[22] https://www.arb.ca.gov/regact/2014/truckbus14/tbfrooal.pdf

4.2.3.9.1.4. SMALL FLEET RULE COMPLIANCE (>26,000 LBS. GVWR)[23]

The Small Fleet Option allowed small fleets to delay vehicle replacements until January 1, 2020 or later for heavier trucks with a gross vehicle weight rating (GVWR) greater than 26,000 lbs. To use this option, owners must have reported their fleet information by January 31, 2014, demonstrated they had at least one PM filter no later than July 1, 2014 and report fleet information each January. The assumptions for small fleets are shown below in Table 4.2-4 for trucks with GVWR above 26,000 lbs. (including single-unit, tractor and interstate IRP trucks).

Table 4.2-4. Retrofit/Replacement Assumptions for >26,000 GVWR Trucks in Small Fleets

By Jan 1	Vehicle Model Year	1st Truck Action	2nd Truck Action	3rd Truck Action
2017	Pre-1996	50% 2012		
2018	Pre-1996	75% 2012		
2019	Pre-1996	100% 2012		
2017	1996-2007		100% DPF	
2017	Pre-1996		25% 2012	
2018	Pre-1996		50% 2012	
2019	Pre-1996		75% 2012	
2020	Pre-1996		100% 2012	
2018	1996-2007			100% DPF
2020	1999 and older	2012	2012	2012
2021	2000-2003	2013	2013	2013
2022	2004-2007	2014	2014	2014
2023	2008-2011	2015	2015	2015

4.2.3.9.1.5. LARGE FLEET RULE COMPLIANCE (>26,000 LBS. GVWR)[24]

Heavier trucks and buses with a GVWR greater than 26,000 pounds must comply with a schedule by engine model year. The assumptions for large fleets in EMFAC2017 are shown below in Tables 4.2-5 through 4.2-7. For EMFAC2017, staff assumed that by January 1, 2014, only 30 percent of pre-2008 trucks within this category were retrofitted with DPF. This assumption was made based on the number of pre-2008 MY trucks in the DMV2016b and the number of retrofits that were sold in California (excluding those retrofits that were used for fleets to meet PAU, Transit, and SWCV rules). EMFAC2014 also included information on the DPF phase-in schedule, early PM credits and Economic Hardship Provisions. Since only a small fraction of trucks use these provisions, CARB staff did not model them in EMFAC2017.

Table 4.2-5. Replacement Assumptions for >26,000 GVWR Out of State Trucks (Large Fleets)

By Jan 1	Vehicle Model Year	Fleet Action (Turnover to)
2017	Pre-1996	2012
2020	1996-1999	2015
2021	2000-2004	2016
2022	2005-2007	2017
2023	2008-2011	2017

[23] https://www.arb.ca.gov/msprog/onrdiesel/documents/FAQsmall.pdf
[24] https://www.arb.ca.gov/msprog/onrdiesel/documents/FSRegSum.pdf

Table 4.2-6. Replacement Assumptions for >26,000 GVWR Tractors (Large Fleets)

By Jan 1	Vehicle Model Year	Fleet Action (Turnover to)
2017	Pre-1996	25% 2012
2018	Pre-1996	50% 2012
2019	Pre-1996	75% 2012
2020	Pre-1996	100% 2012
2020	1996-1999	25% 2015
2021	1996-1999	50% 2015
2022	1996-1999	75% 2015
2023	1996-1999	100% 2015
2021	2000-2004	33% 2016
2022	2000-2004	66% 2016
2023	2000-2004	100% 2016
2022	2005-2007	2017
2023	2008-2011	2017

Table 4.2-7. Replacement Assumptions for >26,000 GVWR Single Unit Trucks (Large Fleets)

By Jan 1	Vehicle Model Year	Fleet Action (Turnover to)
2017	Pre-1996	25% 2012
2018	Pre-1996	50% 2012
2019	Pre-1996	75% 2012
2020	Pre-1996	100% 2012
2020	1996-1999	25% 2013
2021	1996-1999	50% 2013
2022	1996-1999	75% 2013
2023	1996-1999	100% 2013
2021	2000-2004	33% 2014
2022	2000-2004	66% 2014
2023	2000-2004	100% 2014
2022	2005-2007	2015
2023	2008-2011	2015

4.2.3.9.1.6. NO_X EXEMPT AREA EXTENSIONS[25]

The NOx Exempt Area Extension only applies to vehicles that travel exclusively within specified NOx exempt areas, and excludes school buses. These vehicles qualified for PM filter requirements on a delayed schedule and do not need to be replaced after they are equipped with PM filters.

Table 4.2-8. Retrofit Assumptions for >26,000 GVWR Trucks in the NOx Exempt Areas

By Jan 1	Vehicle Model Year	Large Fleets Fleets with>3 Trucks	% of Small Fleet Trucks that must have DPF		
			1 Truck Fleet	2 Truck Fleet	3 Truck Fleet
2017	Pre-2008	55% must have DPF	100%	50%	66%
2018	Pre-2008	70% must have DPF	100%	50%	66%
2019	Pre-2008	85% must have DPF	100%	100%	100%
2020	Pre-2008	100% must have DPF	100%	100%	100%

[25] https://www.arb.ca.gov/msprog/onrdiesel/documents/fsnoxexempt.pdf

Table 4.2-9. Retrofit Assumptions for <=26,000 GVWR Trucks in the NOx Exempt Areas

By Jan 1	Vehicle Model Year	All Fleets (Both Large and Small Fleets have the same requirements)
2017	Pre-1998	100% of these must have DPF
2018	1998	100% of these must have DPF
2019	1999	100% of these must have DPF
2020	2000-2003	100% of these must have DPF
2021	2004-2007	100% of these must have DPF

4.2.3.9.1.7. ASSUMPTIONS FOR TRUCKS <= 26,000 GVWR[26]

This section discusses compliance requirements and options that are available to lighter vehicles. Lighter vehicles are those with a gross vehicle weight rating (GVWR) of 14,001 to 26,000 lbs. These requirements and options do not apply to school buses.

Table 4.2-10. Replacement Assumptions for <=26,000 GVWR Trucks

By Jan 1	Vehicle Model Year	Fleet Action (Turnover to)
2017	Pre-1996	2012
2018	1996	2012
2019	1997	2012
2020	1998	2013
2021	1999	2014
2022	2000-2003	2015
2023	2004-2007	2016
2023	2008-2011	2017

4.2.3.9.1.8. SCHOOL BUS PROVISION

Diesel-fueled school buses with a gross vehicle weight rating (GVWR) over 14,000 lbs. are subject to the Truck and Bus Regulation. Owners needed to retire school buses manufactured before April 1, 1977 by calendar year 2012 and DPFs were required to be installed according to a phase-in schedule that was to be completed by CY2014. EMFAC2017 assumes that all 2-stroke engine buses would be replaced with MY2008 vehicles by January 1, 2018.

4.2.3.9.1.9. PUBLIC/UTILITY/SOLID WASTE COLLECTION VEHICLES[27,28]

California Air Resources Board approved a regulation in 2003 that required diesel-fueled solid waste collection vehicles (SWCV) use CARB verified control technology according to a phase-in schedule that was to be completed by 2010. All pre-2008 diesel SWCV are assumed to have installed DPFs by January 1, 2012. In 2005, CARB approved a regulation to reduce diesel particulate matter (PM) emissions from fleets operated by public agencies and utilities (PAU). All pre-2008 diesel public vehicles operating in higher population regions were assumed to have installed DPFs by January 1, 2013, and for those operating in lower population regions

[26] https://www.arb.ca.gov/msprog/onrdiesel/documents/faqlightertrucks.pdf
[27] https://www.arb.ca.gov/msprog/publicfleets/publicfleetsfactsheet.pdf
[28] https://www.arb.ca.gov/msprog/swcv/trashtruck.pdf

EMFAC2017 assumes that DPF retrofits will be installed by January 1, 2018. For utility trucks, DPF retrofits were assumed to have been completed by January 1, 2011 and EMFAC2017 assumes that all pre-2012 utility vehicles will be replaced with MY2013 vehicles by January 1, 2021.

4.2.3.10. FUTURE DIRECTION

In addition to the previously discussed EMFAC2017 updates, there are important regulatory and statutory considerations related to the heavy-duty fleet characterization that needs to be highlighted.

Updated T&B Compliance Rates. CARB's 2015 Enforcement Report indicated that 25 to 30 percent of diesel trucks in California may be out of compliance with the Truck and Bus Rule. Enforcement staff are continuing to implement "smart audits" that direct efforts for bringing fleets into compliance, especially for fleets with older and higher polluting trucks. The updated calendar year 2016 base-year inventory in EMFAC2017 also reflected potentially non-compliant vehicles. To forecast the inventory into the future, EMFAC2017 has made compliance path assumptions that will bring fleets back into compliance over time to ensure full implementation of the Truck and Bus rule to achieve emission reductions. These compliance paths are described in section 4.2.3.9.

DMV Registration Holds. On April 28, 2017, Governor Brown signed SB-1, a "Transportation Funding" bill that went into immediate effect. This bill included a provision that modified the Vehicle Code to prohibit DMV from registering or renewing the registration of medium and heavy duty diesel trucks unless the truck owner can demonstrate full compliance with applicable emission requirements. CARB is working with DMV to implement a registration hold procedure to meet this new statutory requirement, which will greatly assist CARB with enforcement efforts. Vehicles found not to be in compliance or without sufficient data available to verify compliance with CARB's regulatory programs will need to establish a positive compliance status before they will be able to register with DMV in the near future. Fleets are strongly encouraged to ensure vehicle information in DMV registration and CARB regulatory reporting databases are up-to-date and accurate.

4.3. EMISSION RATES

Emission rates (ER), for both light duty (LD) and heavy duty (HD) vehicles have been updated in EMFAC2017. LD ER updates result from changes in the starts methodology, as well as incorporation of new test data for the cold start and running base emission rates (BERs). Soak correction factor (SoF) curves for LD have also been updated using these new data. These updates are described in section 4.3.1. HD updates include new running exhaust, starts, and idle diesel ERs. New ERs for CNG transit buses have also been developed and implemented within a new transit bus module. These updates are described in 4.3.2.

4.3.1. UPDATES TO LD EMISSION RATES

Emissions that emanate from the vehicle's tailpipe are called exhaust emissions. Incomplete combustion of the fuel is the primary cause of hydrocarbon (HC), carbon monoxide (CO), and particulate matter (PM) emissions. These emissions occur at all times, but are more intense when the air-fuel ratio is richer than stoichiometric (14.7-to-1) conditions, such as during a hard acceleration. Oxides of nitrogen (NO_X) emissions are produced during combustion at high temperatures and pressures, and can be enhanced under lean air-fuel ratio conditions. Properly working catalysts reduce tailpipe emissions from gasoline vehicles by over 90 percent when combined with electronic systems that monitor the air-fuel ratio. Due to higher combustion temperatures, excess air, and high pressures, a diesel-fueled vehicle emits comparatively more NO_X than a gasoline-fueled vehicle. The lean overall air-fuel ratios used by diesel vehicles preclude the use of conventional reduction catalysts for emissions control systems. Combustion engine vehicles also emit carbon dioxide (CO_2) and are a significant contributor to statewide greenhouse gas (GHG) emissions. It should be noted that EMFAC uses measured CO_2 emissions data to predict CO_2 emissions and emission rates.

There are two light duty vehicle operational modes that contribute to exhaust emissions: the stabilized running mode and the start mode. This section provides a brief overview of the model's handling of basic tailpipe emission rates (BERs) and start emission rates. Emission rates (also referred to as emission factors) related to these sources are typically measured at standard temperature and humidity using driving cycles mimicking typical vehicle driving and operating patterns. Emission rates are ultimately combined with vehicle activity data (such as vehicle population counts) to estimate vehicle emissions inventories as shown in equation (4.3-1) below:

$$\text{Emission (tons per day)} = \sum \text{VMT (miles/day)} \times \text{Base Emission Rate (g/mi)} \times \text{Correction Factors} \quad \text{(Eq. 4.3-1)}$$

In EMFAC2017, the BERs used to compute the running and starts emission rates were updated for the first time since EMFAC2000, using accumulated test data. In addition, the derivation method for the starts emission rates was revised. The updated BERs were created from data from CARB's Vehicle Surveillance Program (VSP) and the USEPA's In-Use Verification Program (IUVP). The running exhaust emission rates were computed using data collected in Unified Cycle Phase 2 Testing (UC P2). The starts emission rates were determined using data collected in UC Phases 1 and 3 testing. A critical difference, from prior versions of the model, was in the use of UC data to compute the starts emission rates. In prior versions of the model, it was assumed the starts emission rate could be estimated using the cumulative emissions over the first 100s of UC P1. A data analysis showed that starts emissions occur well beyond 100s. In EMFAC2017, the starts emission rate is modeled using the full 300s of UC P1 and running emissions are subtracted out using UC P3. Another critical update was in the soak correction factor curves (SoFs). These soak time dependent, technology specific equations return scalars that are used to convert cold start emission rates to a warm start emission rates. For EMFAC2017, the SoF equations have been updated using starts testing data from the VSP.

4.3.1.1. LIGHT DUTY BASE EMISSION RATES

The stabilized running mode occurs when the engine and/or catalyst are at normal operating temperatures. As the engine starts cold, it takes between 100 – 300 seconds for the catalyst to achieve its optimal operating temperature range. During this time, the emissions are generally higher as the catalyst efficiency is highly dependent on its temperature. Start emissions also vary by ambient temperature as well as the length of time the vehicle has been soaking (length of time sitting between engine shut-off and start time). Running exhaust emissions may vary by speed, temperature, humidity, and/or air conditioning usage. Most of the passenger cars (PC), light-duty trucks (LDT) and medium-duty vehicles (MDV) exhaust data used for modeling purposes have been collected from CARB's VSP projects, in which vehicles were tested on a chassis dynamometer.

Smog Check inspection and maintenance (I/M) benefits were estimated in the prior versions of EMFAC based on data collected decades ago from vehicles that were subject to (with) Smog Check and vehicles that were not subject to (without) Smog Check. Since today's entire California vehicle fleet has been subject to Smog Check I/M for decades, there are currently no vehicle emission rate data available to represent emission levels for vehicles that are not subject to it. Because of this, the Bureau of Automotive Repair (BAR) and CARB have agreed that starting with EMFAC2017, the California Smog Check I/M Benefits module within EMFAC (CALIMFAC) will be discontinued.

The underlying assumptions in the CALIMFAC module were that the light-duty vehicle fleet can be categorized into unique "technology groups." Each technology group represents vehicles with distinct emission control technologies with similar in-use deterioration rates and response to repairs. Further, vehicles in each technology group can be sub-divided into "emission regimes" which are defined by certification standards (i.e., Standards defined over the Federal Test Procedures – FTP) as shown in Table 4.3-1.

Table 4.3-1: Emission regime definitions in the prior versions of the EMFAC model

Regime	Definition
Super	above 4 times the FTP composite standards
Very High	< 4 times FTP composite standards
High	< 3 times FTP composite standards
Moderate	< 2 times FTP composite standards
Normal	Below FTP composite standards

As vehicles age (or accumulate mileage), their emissions increase as a result of control device performance deterioration. CALIMFAC characterizes this deterioration by migrating these vehicles from the normal emitting regime to higher emitting regimes. Further, CALIMFAC assumes that emissions from vehicles within an emission regime above the normal regime do not increase with mileage accumulation. Hence, emissions characteristics of a vehicle technology group are represented by these emission regimes and vehicle emissions deterioration is simulated by the movement of vehicles across regimes. More details are provided in EMFAC2000 technical support documentation[29].

As mentioned earlier, due to the lack of emission data on newer model years that represent “no-I/M conditions,” CALIMFAC will be discontinued. Therefore, to estimate “excessive emissions,”[30] as required by AB 2289 in the future, CARB and BAR will be working together to develop a more representative approach outside of the EMFAC model. BAR has recently (March 2015) started collecting on-board diagnostic (OBD) only data under the new Smog Check program, pursuant to AB 2289 for MY2000+ vehicles, using their on-board diagnostic inspection system (OIS) data management system. Data from this new system are still in the process of being reviewed by BAR. In addition, limited emission test data (i.e., Acceleration Simulation Mode – ASM – emission testing) on OBD-equipped vehicles will also be available through BAR’s random roadside inspection program[31]. Upon the availability of these data, BAR staff will mine and analyze them to gain a better understanding of the program benefits. Analyses of OIS and roadside ASM data could weigh into the future methodology (outside of the EMFAC model) for estimating “excessive emissions”.

4.3.1.1.1. UPDATED METHODOLOGY

As described in the previous section, to model the effect of deterioration and I/M program, vehicles are sub-divided into “emission regimes” where each regime identified vehicles with certain emission characteristics. In order to calculate the fleet average emission rates (i.e., Basic Emission Rate – BER), emission factors associated with each regime (i.e., Regime

---

[29] EMFAC2000 Tech Document Section 4 at http://www.arb.ca.gov/msei/onroad/downloads/tsd/Basic_Emission_Rates_PartA.pdf
[30] H&SC Sect 44024.5(b)(4) http://www.leginfo.ca.gov/pub/09-10/bill/asm/ab_2251-2300/ab_2289_bill_20100924_chaptered.pdf
[31] http://www.smogcheck.ca.gov/Consumer/Roadside_Inspection_Program.html

emission factor) are weighted using the percent of vehicles within each regime (i.e., regime fractions) as shown below in equation (4.3-2):

$$BER\ (g/mi) = \sum \text{Regime Fraction (Odometer)} \times \text{Regime emission factor (g/mi)} \qquad \text{(Eq. 4.3-2)}$$

In EMFAC2017, staff reduced the number of regimes from five regimes to three as shown in Table 4.3-2. The emission factor for the normal regime is the average emissions for vehicles that meet the FTP emission standards. The emission factor for the moderate regime is the average FTP emissions of vehicles that have emissions between 1 and 2 times the standard, and the emission factor for the high regime is the average emissions of vehicles that have emissions more than 2 times the standard.

Table 4.3-2: Emission regime definitions in EMFAC2017 model

Emission Regime	Emission Range
Normal	0 to 1.0 x Standard
Moderate	1.0 to 2.0 x Standard
High	>2.0 x Standard

In EMFAC2014 and previous versions, there were very high and super emitter levels that could be improved by the action of inspection and maintenance, and reduced to Normal or Moderate emitter levels. Because in EMFAC2017, BER data will be correlated from vehicles subject to and repaired by the California Smog Check program, the *Very High* and *Super* emitter levels were subsumed into the *High* emitter level.

4.3.1.1.2. MODIFIED LA92 (UC CYCLE)

Since at least 2001, CARB has been collecting LA92 (referred to as the Unified Cycle - UC) in a modified manner. The official LA92 has 30 seconds of idle before drive off in bags 1 and 3. The modified LA92 used by CARB reduces the upfront idle to 20 seconds, with the additional 10 seconds added to the end of bags 1 and 3. Therefore, the overall cycle time, distance, and idle time is unchanged, and bag 2 has not been modified.

This has not been previously documented and CARB has not identified any documentation as to the rationale. The CARB is documenting this change now, as the cycle has become commonly used outside of California. This change may be important to U.S. EPA or others using the LA92 for starts emissions. That is, the reduced 10 seconds of idle could have a disproportionately large effect on the cold start emissions in that it may change the catalyst temperature warm-up profile. A comparison of the speed-time profile of the two cycle variants is shown in Table 6.4-1.

Discussion and Future Direction

As mentioned previously, CARB has effectively always used the modified LA92 cycle. Therefore, there is no change in methodology or emissions. This section of the documentation is written because it has not been previously communicated to stakeholders. Based upon the initial research that developed the LA92[32], CARB staff believes 20 seconds vital is more appropriate. For the rest of this document the LA92 should be considered the modified version. Since this is consistent with how CARB has always collected the data, there is no modification being planned. Staff is concerned that should the LA92 become a regulatory cycle, consideration should be given to the associated start emissions. CARB will conduct further testing to see if idle time in general significantly affects the start emissions.

4.3.1.1.3. DEFINITION OF TECHNOLOGY GROUPS

The existing LEV program regulates emissions from new light-duty vehicles for sale in California. Vehicle categories covered under the program include all passenger cars, light trucks, and medium-duty passenger vehicles (note that a full list of technology groups can be found in Appendix 6.2). For example, the current set of standards for the LEV II program includes the emission category designations of Low-Emission Vehicle (LEV), Ultra-Low Emission Vehicle (ULEV), and Super Ultra-Low Emission Vehicle (SULEV). Compliance with California and Federal Standards is done based on the emission results with the Federal Test Procedure (FTP), which uses the LA4 driving-cycle. The emission factors used in the EMFAC model are based on the Unified driving-cycle (UC) which is the same as LA-92 cycle. This driving-cycle is thought to be closer to average driving in California.

CARB first adopted LEV standards in 1990. The first LEV standards run from 1994 through 2003. This first set of standards, known as LEV I, introduced several emission categories, such as LEV and ULEV, that car manufacturers were required to certify vehicles' emissions to in order to be able to sell them. In November of 1998, CARB adopted the Low Emission Vehicle II (LEVII) program, which calls for lower exhaust and evaporative emissions standards for new passenger cars, light-duty and medium-duty trucks beginning in 2004. Under the LEV II regulation, the light-duty truck and medium-duty vehicle categories at or below 8,500 lbs. GVWR were reclassified and had to meet passenger car requirements. Under LEV II, three sets of increasingly more stringent emission standards were defined: LEV, ULEV, and SULEV. A fourth emission category, PZEV (partial zero emission vehicle), had the same test emission levels as SULEV, but also included a "zero" evaporative emissions standard and a 150,000-mile/15-year emission durability. LEV I and LEV II emission standards for FTP-75 testing are summarized in Table 4.3-3.

[32] Sierra Research, "Characterization of Driving Patterns and Emissions from Light Duty Vehicles in California", Table 32, November 1993

Table 4.3-3. LEV I and LEV II emission standards for passenger cars and LDTs ≤ 8,500 lbs. (LDT1 & LDT2), FTP-75, g/mi

Program	Cert Level	Model Years	Durability (mi)	EMFAC Tech Group	NMOG Standard (g/mi)	NO_X Standard (g/mi)	CO Standard (g/mi)
LEV II	PZEV	2004-2014	150,000	31	0.010	0.020	1.0
LEV II	L2ULEV	2004-2014	120,000	29	0.055	0.070	2.1
LEV II	L2LEV	2004-2014	120,000	28	0.090	0.070	4.2
LEV I	ULEV	1994-2003	100,000	24	0.055	0.300	2.1

4.3.1.1.4. DATA SOURCES

To update base emission rates in the EMFAC model, three major data sources were mined and analyzed:

U.S. EPA's IUVP Database. EPA mainly relies on the manufacturer-run In-Use Verification Program (IUVP) to monitor the performance of vehicles during their useful life since model-year 2004. IUVP tests are required at low mileage (at least 10,000 miles) and high mileage (more than 50,000 miles). The manufacturer must complete low-mileage IUVP testing within one year after the end of production of the test group and high-mileage IUVP testing must be done between four years and five years of the end of production of the test group. Additionally, at least one of the high-mileage vehicles must have a minimum odometer mileage of 75 percent of the useful life. The results must be reported to US EPA according to set schedules, and the regulations specify the number of vehicles that must be tested for each group. This varies between two and six vehicles per test group based upon the overall sales of the test group and whether the low or high mileage test point is involved. For test groups in the 50,001-250,000 annual sales range, three vehicles must be tested at the low mileage point and five at high mileage. For test groups with over 250,000 annual sales, the low and high mileage number of vehicles required are four and six, respectively.

As of February 2016, IUVP contains 1000 non-replicate, non-void data points for partial zero emission vehicles (PZEVs), 4500 data points for L2ULEVs, and 2100 data points for L2LEVs. IUVP data on the FTP were used to determine the fractions of normal, moderate and high emitters versus odometer for L2LEVs, L2ULEVs and PZEVs.

The IUVP results were weighted by the California sales of each test group. The IUVP data includes results of each and every car engine family or test group in a model year. Test groups that have high sales are required to submit results from more individual vehicles. This makes the families with high sales or high number of replicates more important to the average. The sales weighting is meant to apply the proper importance to individual families' results. Sales data were obtained from the manufacturers' non-methane organic gas (NMOG) reports to CARB, which is described next.

Certification's NMOG Reports. CARB emission regulations require each manufacturer meet a certain average NMOG exhaust value for each model year. The fleet averages decrease every succeeding model year. Therefore, manufacturers must report the sales by test group or engine family. Manufacturers also report each engine family's emissions as part of the new-car certification procedure. The NMOG emissions-value for each engine family is sales-weighted to determine the compliance with CARB fleet emission limits. NMOG Reports are end-of-year reports submitted by LD manufacturers, which provide actual California sales volume by model and engine family. These data allow CARB to assess manufacturer compliance with the NMOG fleet-average emission standards required by the LEV program.

Vehicle Surveillance Program. CARB conducts vehicle surveillance programs (VSP) at Haagen Smit Laboratory (HSL). CARB typically recruits vehicles from vehicle owners in Southern California by random selection. Special attention is paid to vehicles with issues of past emissions performance, or vehicles that adopted new technologies, in order to gain a better understanding of how new technologies are working. On average, CARB tests approximately 40 vehicles per year. Compared to the number of vehicles tested by the manufacturers (described above), CARB only tests a small portion of the vehicles. Since 2006 in the vehicle surveillance programs, each car is tested on both the FTP and UC, in order to form a picture of emission rate on the standard compliance cycle as well as on "average driving".

CARB VSP data for cars under both the UC and the FTP used to correlate between FTP emission levels and UC emission levels, giving the UC-based emission levels for the emission regimes. The emission rates are correlated in terms of fraction of vehicles in an emission regime (either normal-, moderate-, or high-emission) (a function of odometer), averaging the corresponding UC emission rate over odometer bin for that regime. For simplification in the program, the curve of the averages vs odometer is curve-fitted. For PZEVs, the emission regime levels were based on 30 points, which had both FTP and UC tests. For L2ULEVs, CARB based the emission regime levels on 44 points, which had both FTP and UC tests. For L2LEVs CARB based the emission regime levels on 32 points that had both FTP and UC tests. For the ULEVs (L1ULEVs), we based regime levels on 52 points that had both FTP and UC tests. For the LEVs (L1LEVs), we based regime levels on 129 points that had both FTP and UC tests. Since the IUVP program started in about 2004, there was no data for FTP regime fractions for the LEV I and pre-LEV emission levels (1985-1993 MY levels). Therefore, CARB Surveillance and Research FTP tests – 75 FTP tests for ULEVs, and 188 FTP tests for LEVs – were used. For the pre-LEV cars, the tested population's UC Bags 1, 2, and 3 results were correlated against odometer readings. There were 261 non-replicate UC tests on these model year cars.

The EMFAC model BERs for organic gas emissions is for Total Hydrocarbons, which is abbreviated as "THC" or just "HC". The test instrument for these emissions only detects compounds of H and C only (hydrocarbons). These are the predominant species in liquid gasoline. Methane, a hydrocarbon, is considered non-photochemically reactive, thus is deducted from smog-making organic emissions. The result is Non-methane Hydrocarbons or NMHC. As a result of partial combustion, exhaust gases might contain unburned gasoline (hydrocarbons) and partially-oxidized organics such as aldehydes, alcohols, and ketones. The partially oxidized organics are detected by another analysis. The combined results of the hydrocarbons and partially-oxidized species is called Total Organic Gases or TOG. Subtracting methane makes Non-methane Organic Gases or NMOG. Subtracting non-reactive partially-oxidized species such as acetone from NMOG makes the Reactive Organic Gases or ROG. The emissions regulations are written in terms of NMOG. The emission tests results are typically THC, often with methane quantified separately. IUVP data for organic gases is given as NMOG.

4.3.1.1.5. MAJOR UPDATES

As part of this update, staff analyzed IUVP emission data to determine emission regime fractions, as a function of odometer and emissions group, using the following three regimes:

- Normal: Below standards
- Moderate: Below 2x standards
- High: Above 2x standards

The IUVP regime fractions were transformed to California fleet regime fractions through weighting using data from the CARB's Certification NMOG Reports. FTP test results from VSP used to assign VSP vehicles to the regimes and the average UC results of the vehicles in the regimes will be computed from the VSP UC test results. The UC BERs were then computed by fraction weighted averaging over the average emission rates of the three regimes:

$$\text{UC BER} = \sum_{\text{Regime}} \text{Regime Fraction} * \text{Regime UC ER} \qquad \text{(Eq. 4.3-3)}$$

Note that the regime fractions are used in the EMFAC2017 computer program as continuous function of odometer and allows for the modeling of deterioration in the LD fleet. The emission results were binned by odometer, usually in 50 kmi bins (0-50 kmi, 50-100 kmi, 100-150 kmi, etc.). To get the emission regime levels, the average emission was calculated by regime for each odometer bin, and plotted vs the average odometer. To get the regime fractions for each odometer bin, the fractions of normal, moderate, and high emitters were calculated and plotted vs average odometer.

4.3.1.1.6. PZEV

The PZEV (partial zero-emission-vehicle credit) emission level was first established for the 2004 model year. This emission level has the cleanest cars and is the basis of progress in the future. About 2012, in-use data became available in sufficient numbers from CARB VSP and U.S. EPA IUVP programs. To update base emission rates for PZEVs, the following steps were taken:

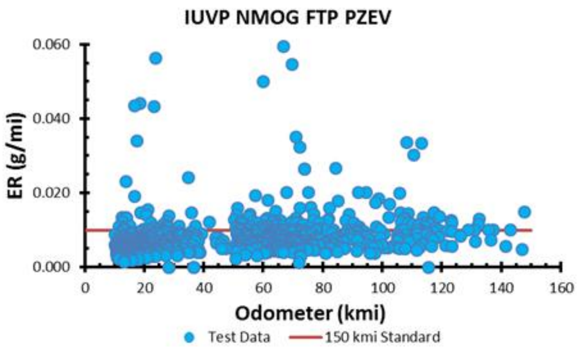
1. Gather the IUVP data (FTP results) for PZEVs.
2. Gather the California sales for each test group.
3. Determine the weighted regime fractions and averages vs odometer for the FTP data.
4. Gather the universe of PZEV tests from VSP under the FTP and the UC tests.
5. Classify the FTP tests by normal, moderate and high emission regimes.
6. Select the tests of cars under both the FTP and UC
7. Determine the average value of UC results for each emission regime.

It needs to be mentioned that staff followed same procedure to analyze data for LEVII ULEV, LEVII LEV, ULEV, and LEV technologies.

4.3.1.1.6.1. FTP RESULTS

Figure 4.3-1 shows the universe of FTP composite emission rates versus odometer for PZEV cars from the IUVP data. There are 962 data points. NO_X and NMOG 150,000-mi standards are also shown.

Figure 4.3-1: IUVP NMOG and NO_X FTP Composite emission rates (g/mi) vs. Vehicle Mileage (Odometer)

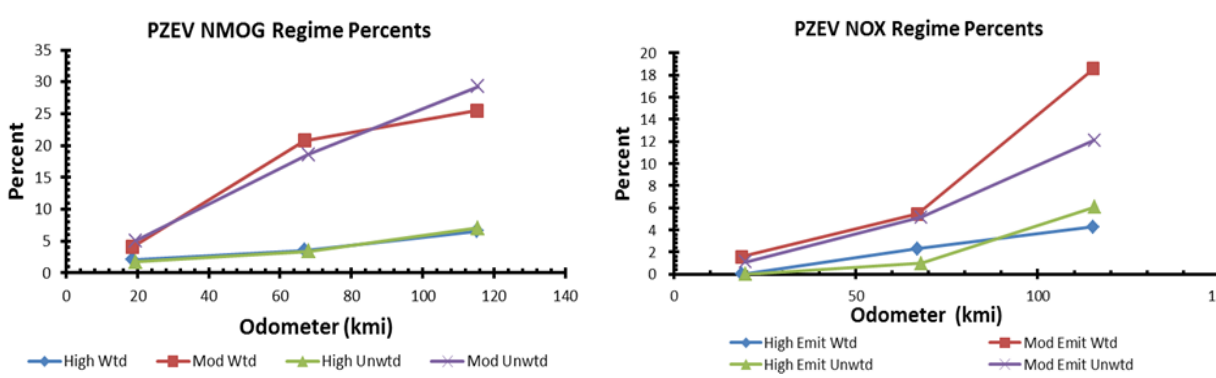


In general, the NO_X values are slightly higher than the NMOG values, and have few readings above 20 mg/mi. However, in Figure 4.3-1, high number of the NMOG emission points are greater than the standard (in the Moderate and High emission regimes). Under LEV II program, the 150,000-mi standards are 10 mg/mi for NMOG and 20 mg/mi for NO_X. Under LEV III the standard is 30 mg/mi for the sum of NMOG plus NO_X.

4.3.1.1.6.2. SALES WEIGHTING, REGIME FRACTIONS

The IUVP data for PZEVs consisted of eight model years (2006 to 2013). There were 962 individual cars in 225 test groups where some test groups were represented by as many as 20 cars, but the average was 4.5 cars per test group. Rather than using weighting factors from IUVP data, CARB weighted by California sales, which are provided through NMOG reports provided by the manufacturers. According to 2006 through 2013 California NMOG reports, there were 2,563,800 PZEVs sold in the 225 test groups across all eight model years. Figure 4.3-2 shows the weighted vs unweighted fractions in the moderate and high emission regimes.

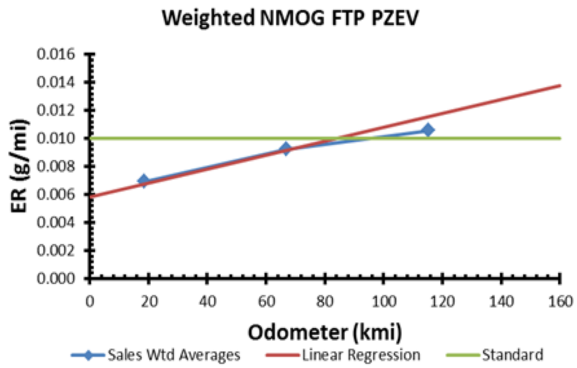
Figure 4.3-2: Weighted and unweighted regime fractions for moderate and high emission regimes as a function of vehicle mileage (odometer)

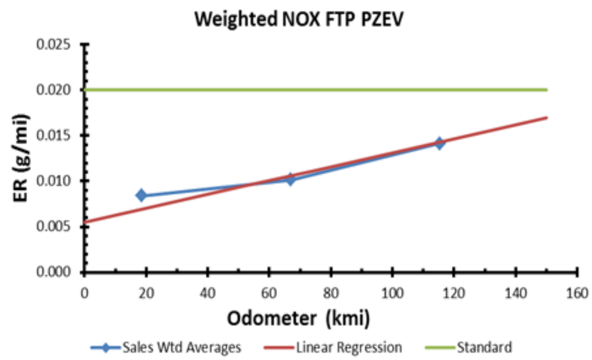


The IUVP data for PZEVs showed relatively high fractions of Moderate and High emitters for NMOG. For NMOG, sales-weighting resulted in a lower moderate fraction over the 100-150 kmi range. For NO_X, sales weighting boosted the regime fraction of highs in the 50 to 100 kmi range, and reduced the fraction in the 100 to 150 kmi range. Sales weighting boosted the fraction of moderates in the 100 to 150 kmi range.

Figure 4.3-3 shows the resulting products of regime fractions and FTP based emission factors derived from IUVP data. The blue points are the average emissions for each odometer bin, the red line is the least-squares regression line for the clouds in Figure 4.3-1 and the green line is 150,000-mi standard for PZEVs.

Figure 4.3-3: Weighted average FTP emission rates (g/mi) as a function of vehicle mileage (odometer)





As shown in Figure 4.3-3, the sales-weighted averages almost exactly match the linear regression lines, the NMOG averages cross the standard level at about 80 kmi, and the NO_X emissions for PZEVs are well below the standard level.

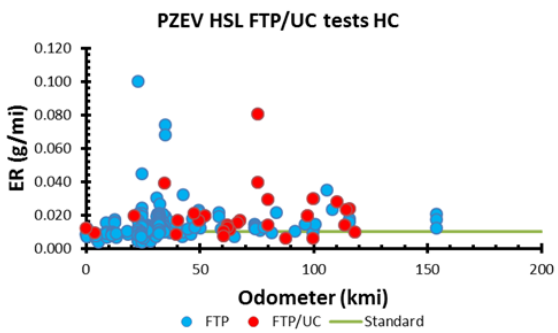
EMFAC uses data from the UC driving cycle as representative of California driving, rather than FTP results. Because of the relatively large number of samples of FTP data, CARB uses the fractions in the normal, moderate and high regimes from FTP data directly, but with average emission factors for normal, moderate and high emitters on the UC driving cycle for EMFAC.

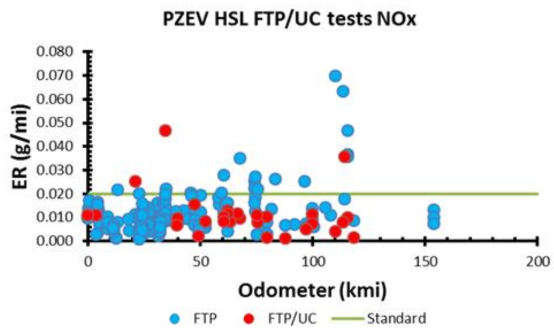
4.3.1.1.6.3. UC RESULTS OF HIGH, MODERATE, NORMAL FTP REGIMES

Since EMFAC uses the emission values from the UC cycle, the UC emission results for each regime were obtained by averaging the results from each FTP-based regime. For this, results from FTP and UC tests on the same vehicles were needed.

The VSP has done many tests for PZEVs on the FTP and UC driving cycles. Figure 4.3-4 shows the NO_X and HC FTP composite emissions rates (g/mi) with the blue circles. The red circles are data points for vehicles that have both FTP and UC tests. As shown in this figure, data from this program covers a wide range of vehicle mileages and contains vehicles with different levels of emissions (i.e., normal, moderate, and high).

Figure 4.3-4: FTP test results for PZEV vehicles tested under CARB VSP program.





There are 219 FTP tests of which 29 are associated with vehicles that have undergone both FTP and UC tests. The tests are first categorized with both FTP and UC tests as high, moderate, or normal regimes based on their initial FTP results. Then, we gather the average emission rate values for the UC test by regime assuming that a high-emission-regime test under the FTP will also be a high-emitter under the UC test. Depending on the emission control component failure that is causing high emissions, vehicles may have different emission performance under FTP versus UC cycle. A high-emitter vehicle under the FTP may not necessarily be a high-emitter under the UC cycle. FTP tests for PZEV vehicles (collected as part of CARB's VSP) are classified in different emission regimes. The average values for the UC results corresponding to those tests by regime and bag are listed in Tables 4.3-4 through 4.3-6.

Table 4.3-4: PZEV HC Emission Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High	6	>0.020	0.211	0.009	0.027
Moderate	17	0.010 to 0.020	0.155	0.005	0.016
Normal	7	< 0.010*	0.077	0.002	0.006

*Certification Standard

Table 4.3-5: PZEV NO_X Emission Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High	2	>0.040	0.630	0.099	0.020
Moderate	6	0.020 to 0.040	0.231	0.023	0.011
Normal	37	<0.020*	0.069	0.009	0.007

*Certification Standard

Table 4.3-6: PZEV CO Emission Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High		>2.0	5.1**	0.8**	2.0**
Moderate	3	1.0 to 2.0	5.1	0.8	2.0
Normal	42	<1.0*	1.8	0.3	0.3

*Certification Standard
**No observed points. Moderate values used.

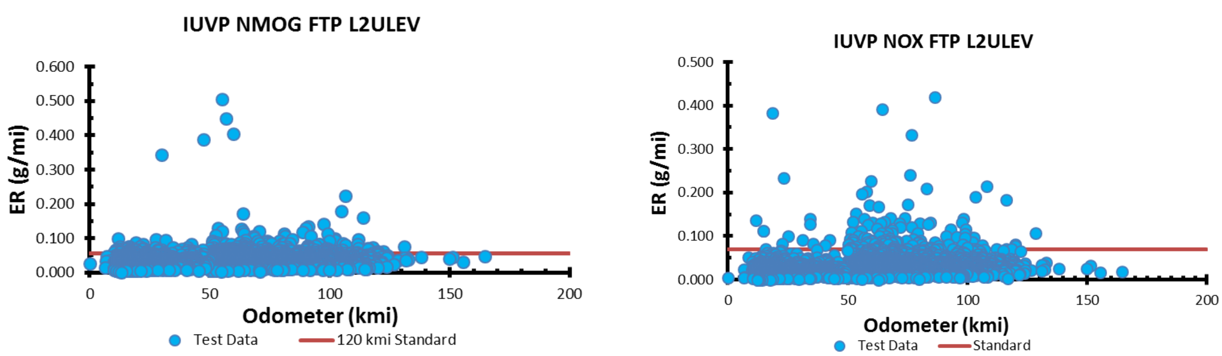
4.3.1.1.7. L2ULEV

LEVII Ultra Low Emission Vehicles (L2ULEV) is an emission category identified under LEV II program with hydrocarbon and carbon monoxide emissions levels nearly 50 percent lower than those of a LEV II-certified vehicle. L2ULEV vehicles have intermediate (50,000 miles/5 years) NMOG and NO_X standards of 0.040 and 0.05 g/mi, and full useful life (120,000 miles/11 years) NMOG and NO_X standards of 0.055 and 0.07 g/mi. To update base emission rates for L2ULEVs, staff followed similar steps as described earlier for PZEVs.

4.3.1.1.7.1. FTP RESULTS

Figure 4.3-5 shows the universe of FTP composite emission rates versus odometer for L2ULEV cars from the IUVP data. There are 4,527 data points. Figure 4.3-5 also shows the NO_X and NMOG 120,000-mi standards. Below the red line is the normal emission regime. Above the red line are the moderate and high regimes.

Figure 4.3-5: IUVP NMOG and NO_X FTP Composite emission rates (g/mi) vs. Vehicle Mileage (Odometer)

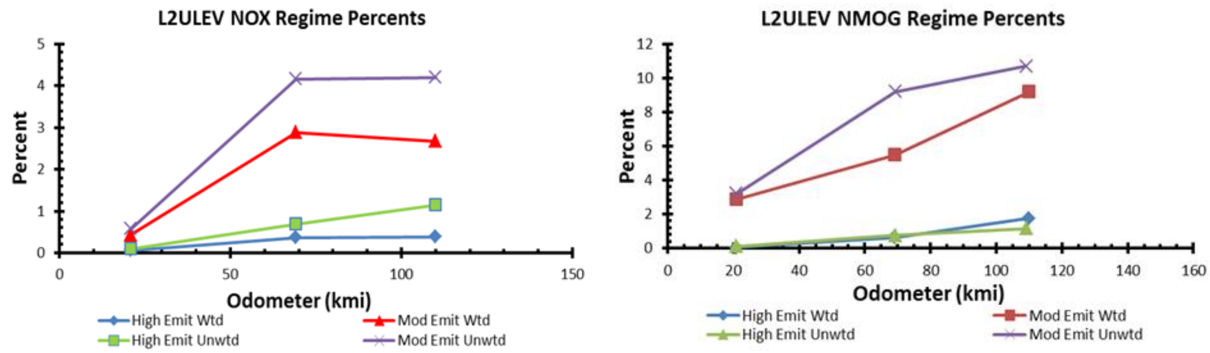


For NO_X, most points fall in the normal regime. For NMOG, a significant percentage was above the standard. As mentioned earlier, under LEV II the 120,000-mi standards are 55 mg/mi for NMOG and 70 mg/mi for NO_X. Under LEV III the standard is 125 mg/mi for the sum of NMOG and NO_X.

4.3.1.1.7.2. SALES WEIGHTING REGIME FRACTIONS

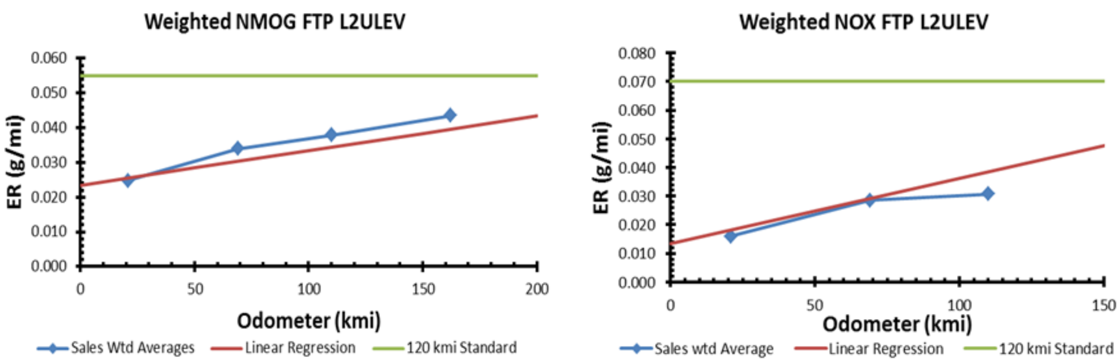
The IUVP data for L2ULEVs consisted of eight model years (2006 to 2013), 4,527 individual cars in 1,036 test groups. Some test groups were represented by as many as 20 cars, but the average was 4.4 cars per test group. Rather than calculating straight average of test results, we thought it fair to weight data by California sales, which is provided by the manufacturers by test group as part of the NMOG reports. In the eight model years, there were 6,180,000 L2ULEVs sold in the 1,036 test groups. Figure 4.3-6 shows the weighted and unweighted fractions in the moderate and high emission regimes.

Figure 4.3-6: Weighted and unweighted regime fractions for moderate



For NMOG and NO_X, sales weighting lowered the sales fraction of moderates. Figure 4.3-7 shows the resulting products of regime fractions and FTP-based emission factors derived from IUVP data. The blue points are the average emissions for each odometer bin, the red line is the least-squares regression line for the clouds in Figure 4.3-5, and the green line is 120,000-mi standard for L2ULEVs.

Figure 4.3-7: Weighted average FTP emission rates (g/mi) as a function of vehicle mileage (odometer)

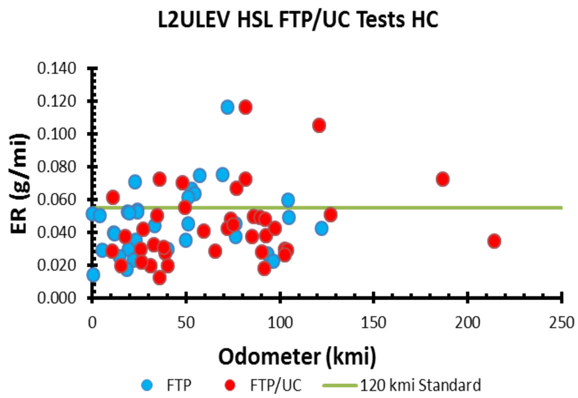


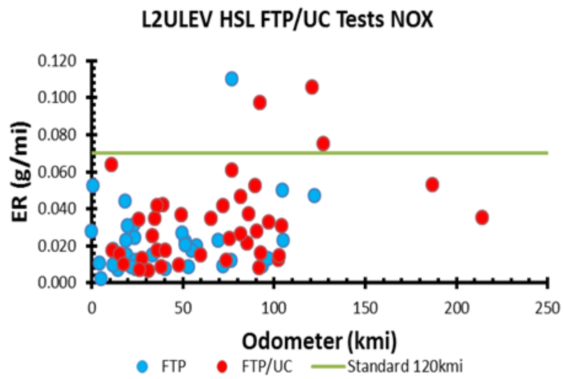
For NO_X, the sales-weighted averages almost match the linear regression line. The NMOG and NO_X fleet results for L2ULEVs are well below the 120,000-mi standard.

4.3.1.1.7.3. UC RESULTS OF HIGH, MODERATE, NORMAL FTP REGIMES

Similar to the analysis done for PZEVs, the UC emission results for each regime were obtained by averaging the UC results from each FTP-based regime. For these, results from FTP and UC tests on the same vehicles were needed. Figure 4.3-8 shows the NO_X and HC FTP composite emissions rates (g/mi) with the blue and red circles as data points for vehicles that have both FTP and UC tests. As shown in this figure, data from this program covers a wide range of vehicle mileages (0 – 200 kmi) and contains vehicles with different levels of emissions (i.e., normal, moderate, and high).

Figure 4.3-8: FTP test results for L2ULEV vehicles tested under CARB VSP program.





There are 72 FTP tests of which 44 are associated with cars that have undergone both FTP and UC tests. As described previously, the tests are categorized with both FTP and UC tests as high, moderate, or normal regimes based on their FTP results. Then, the average emission rate values are gathered for the UC tests by regime, assuming that a high-emission-regime test under the FTP will also be a high-emitter under the UC test. The average values for the UC results corresponding to those tests by regime and bag are listed in Tables 4.3-7, 4.3-8, and 4.3-9 below.

Table 4.3-7: L2ULEV HC Mean Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High	2	>0.110	0.663	0.041	0.052**
Moderate	8	0.055 to 0.110	0.636	0.018	0.052
Normal	34	<0.055*	0.401	0.009	0.025

*Certification Standard.

**Original value was less than moderate level. Moderate value was substituted.

Table 4.3-8: L2ULEV NO_X Mean Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High		>0.140	0.510**	0.070**	0.252**
Moderate	3	0.070 to 0.140	0.510	0.070	0.252
Normal	41	<0.070*	0.192	0.021	0.037

*Certification Standard

**No observed points. Moderate values used.

Table 4.3-9: L2ULEV CO Mean Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High	1	>4.2	8.9**	2.0	3.5
Moderate	1	2.1 to 4.2	8.9	1.1	0.7
Normal	42	<2.1*	4.5	0.6	0.6

*Certification Standard

**No observed points. Moderate values used.

In Table 4.3-7, for NMOG, the resulting UC Bag 1 regime emission values were close together for the High and Moderate regimes. Likewise, the Bag 3 emission rate for the High regime was lower than that for the Moderate regime, and thus led to a low increase of emissions as a function of odometer. This is an artifact of having only two data points for the high regime. This leads to a low contribution of the high regime to the total emissions. In Table 4.3-8, for NO_X, there were no observations of High Emitters among the 44 cars with both FTP and UC tests. This inherently means the contribution of high emitters will be small or zero. In Table 4.3-9 for CO, the UC Bag 1 value for the High regime was lower than for the Moderate regime, probably an artifact of having only one data point for the High regime. In any case, since most observations are in the Normal regime, the High regime values will have negligible effect on the total emissions.

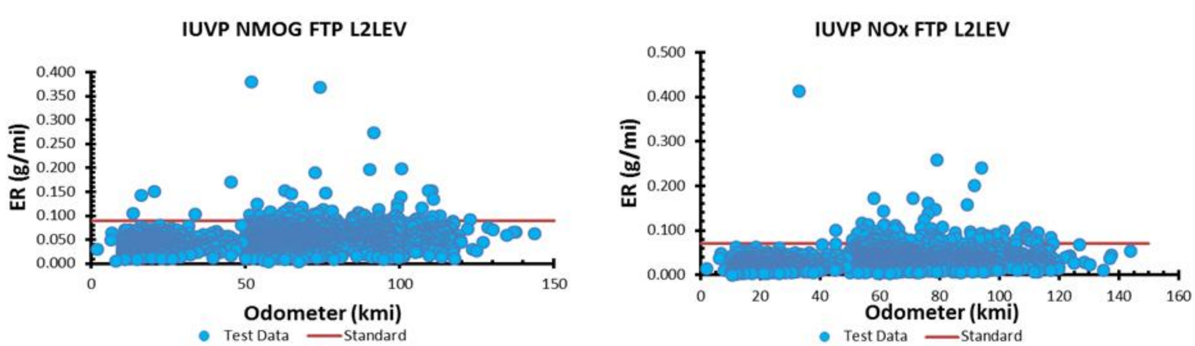
4.3.1.1.8. L2LEV

LEVII Low Emission Vehicle (L2LEV) is the least stringent emission category identified under LEVII program. LEVII LEV vehicles have intermediate (50,000 miles/5 years) NMOG and NO_X standards of 0.075 and 0.05 g/mi, respectively, and full useful-life (120,000 miles/11 years) NMOG and NO_X standards of 0.090 and 0.07 g/mi. To update base emission rates for L2LEVs, staff followed similar steps as described earlier for PZEVs.

4.3.1.1.8.1. FTP RESULTS

Figure 4.3-9 shows the universe of FTP composite emission rates versus odometer for L2LEV cars from the IUVP data with 2,135 data points, and shows the FUL NO_X and NMOG 120,000-mi standards. Below the red lines are the Normal emission regimes; above are the Moderate and High emission regimes.

Figure 4.3-9: IUVP NMOG and NO_X FTP Composite emission rates (g/mi) vs. Vehicle Mileage (Odometer)

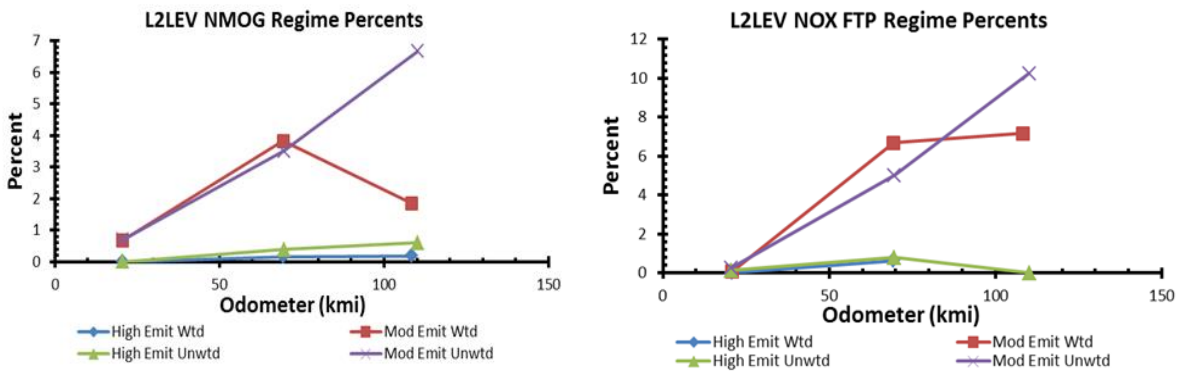


For both NMOG and NO_X, most points fall in the normal regime. As mentioned earlier, under LEV II the 120,000-mi standards are 90 mg/mi for NMOG and 70 mg/mi for NO_X. Under LEV III the standard is 160 mg/mi for the sum of NMOG plus NO_X.

4.3.1.1.8.2. SALES WEIGHTING, REGIME FRACTIONS

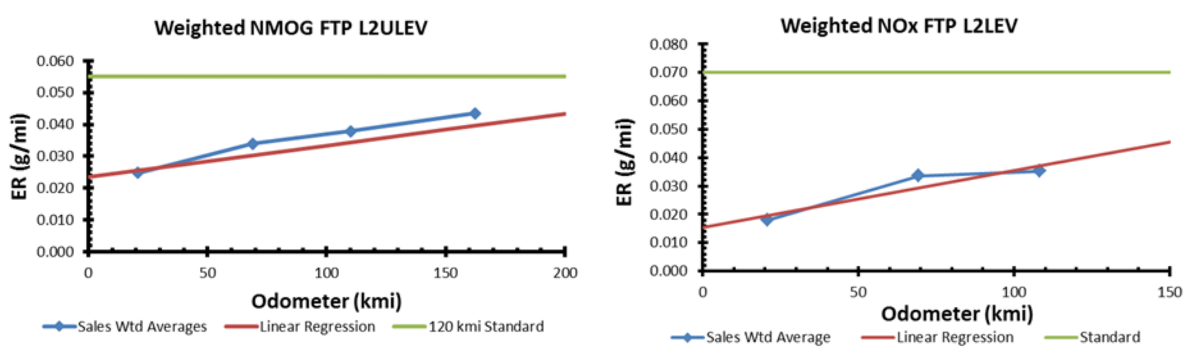
The IUVP data for L2LEVs consisted of eight model years (2006 to 2013), 2,135 individual cars in 481 test groups. Some test groups were represented by as many as 20 cars, but the average was 4.4 cars per test group. Similar to other technology groups, CARB used sales data from NMOG reports to weight emission data by California sales. In the eight model years, there were 1,650,000 L2LEVs sold in California in the 481 test groups. Figure 4.3-10 shows the weighted and unweighted fractions in the moderate and high emission regimes.

Figure 4.3-10: Weighted and unweighted regime fractions for moderate and high emission regimes as a function of vehicle mileage (odometer)



For NMOG, sales weighting lowered the fraction of moderates and highs only at 120 kmi odometer. For NO_X, sales weighting radically lowered the fraction of moderates at 120 kmi, but had absolutely no effect on the high regime fractions. Figure 4.3-11 shows the resulting products of regime fractions and FTP based emission factors derived from IUVP data. The blue points are the average emissions for each odometer bin, the red line is the least-squares regression line for the clouds in Figure 4.3-9 and the green line is 120,000-mi standard for LEVs.

Figure 4.3-11: Weighted average FTP emission rates (g/mi) as a function of vehicle mileage (odometer)

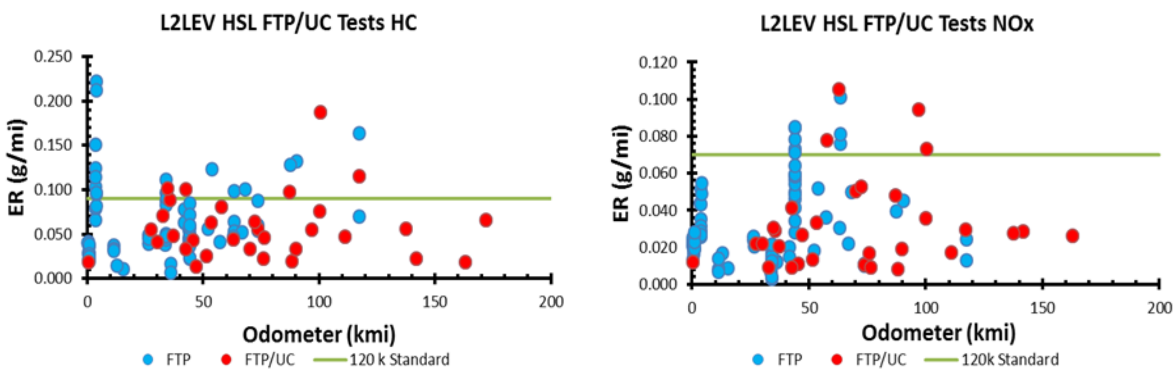


For both NMOG and NO_X, the sales-weighted averages almost match the linear regression lines. Results for both NMOG and NO_X are well below the 120,000-mi standard.

4.3.1.1.8.3. UC RESULTS OF HIGH, MODERATE, NORMAL FTP REGIMES

Similar to the analysis done for PZEVs, the UC emission results for each regime were obtained by averaging the UC results from each FTP-based regime. For this, results from FTP and UC tests on the same vehicles were needed. Figure 4.3-12 shows the NO_X and HC FTP composite emissions rates (g/mi) with the blue and red circles as data points for vehicles that have both FTP and UC tests. As shown in this figure, data from this program covers a wide range of vehicle mileages (0-150 kmi) and contains vehicles with different levels of emissions – in this case normal, moderate, and high.

Figure 4.3-12: FTP test results for L2LEV vehicles tested under CARB VSP program.



There are 119 FTP tests of which 32 are associated with cars that have undergone both FTP and UC tests. The tests are first categorized as high, moderate, or normal regimes based on their FTP results. Then, the average emission rate values for the UC test are gathered by regime, assuming that a high-emission-regime test under the FTP will also be a high-emitter under the UC test. The average values for the UC results corresponding to those tests by regime and bag are listed in Tables 4.3-10 through 12 below.

Table 4.3-10: L2LEV HC Mean Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High	1	>0.180	2.083	0.063**	0.077**
Moderate	4	0.090 to 0.180	0.820	0.039	0.058
Normal	27	<0.090*	0.594	0.014	0.039

*Certification Standard.

**Original values were less than moderate level. High values were linearly extrapolated.

Table 4.3-11: L2LEV NO_X Mean Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High	1	>0.140	0.857	0.107	0.373
Moderate	4	0.070 to 0.140	0.300	0.072	0.126
Normal	34	<0.070*	0.180	0.024	0.023

*Certification Standard

Table 4.3-12: L2LEV CO Mean Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High		>8.4	8.1**	1.2**	1.4**
Moderate		4.2 to 8.4	8.1**	1.2**	1.4**
Normal	39	<4.2*	8.1	1.2	1.4

*Certification Standard

**No observations. Normal values substituted.

In Table 4.3-10, for HC, the resulting UC Bag 2 and Bag 3 emission rates for the High regime were less than the value for the Moderate regime. This led to a low increase of emissions as a function of odometer. This is an artifact of having only one data point for the high regime, leading to a low contribution of the high regime to the total emissions. In Table 4.3-11, for NO_X, there was only one observation of High Emitters among the 32 cars with both FTP and UC tests. This inherently means the contribution of high emitters will be small. In Table 4.3-12 for CO, there were no observations of Moderate or High emitters among the 32 cars. This will make the emission rate for CO invariant with odometer.

4.3.1.1.9. ULEV

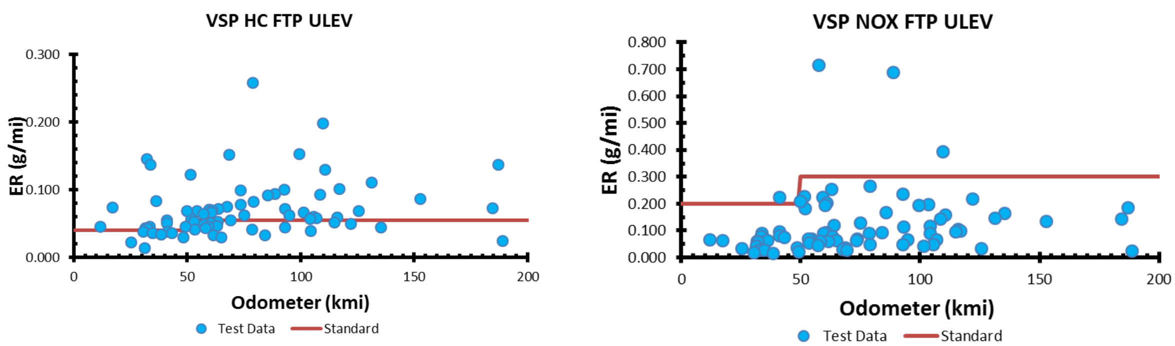
As described earlier, the IUVP program started about 2004 and therefore does not include data for LEV I ULEVs and LEVs, which were manufactured between 1994 to 2003. To update the base emission rates for LEV I categories, CARB relied solely on the UC and FTP data from the CARB's VSP. ULEV (Ultra-low Emission Vehicle) is an emission category identified under the LEV I program with hydrocarbon and carbon monoxide emissions levels nearly 50 percent lower than those of a LEV certified vehicles. ULEVs have intermediate (50,000 miles/5 years) NMOG and NO_X standards of 0.040 and 0.2 g/mi respectively, and full useful life (120,000 miles/11 years) NMOG and NO_X standards of 0.055 and 0.3 g/mi. To update base emission rates for ULEVs, the following steps were taken:

i. Gather the FTP data for ULEVs from CARB's VSP
ii. Classify FTP composite emission rate data by normal, moderate and high regimes
iii. Determine the regime fractions and average emission rates vs odometer for the FTP data
iv. Gather the universe of ULEV tests from HSL under the UC
v. Select the tests of cars under both the FTP and UC
vi. Determine the average value of UC results for each emission regime

4.3.1.1.9.1. FTP RESULTS

Figure 4.3-13 shows the universe of FTP composite emission rates (total of 75 data points) versus odometer for ULEV cars tested under CARB's VSP. Figure 4.3-13 also shows the NO_X and NMOG 50,000-mi and 100,000-mi standards. Below the red line is the Normal emission regime, above are the Moderate and High emission regimes.

Figure 4.3-13: VSP HC and NO_X FTP Composite emission rates (g/mi) vs. Vehicle Mileage (Odometer)

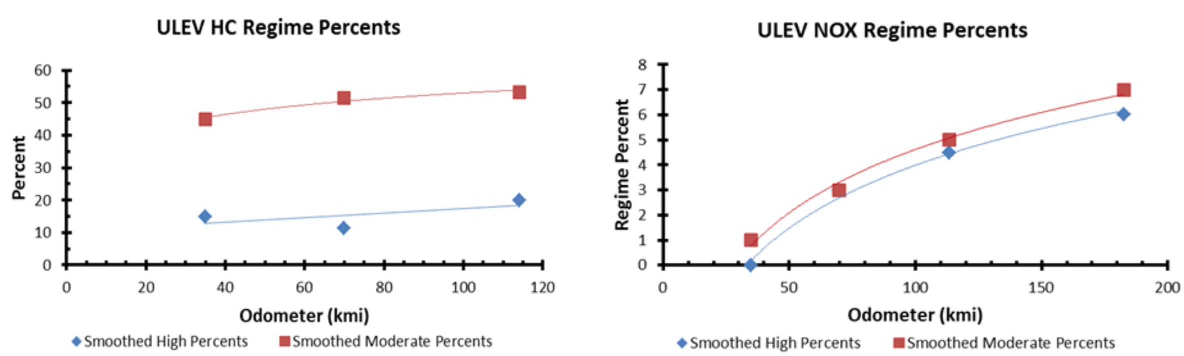


For HC most of the points are above the standard; whereas for NO_X very few points fell above the standard.

4.3.1.1.9.2. SALES WEIGHTING, REGIME FRACTIONS

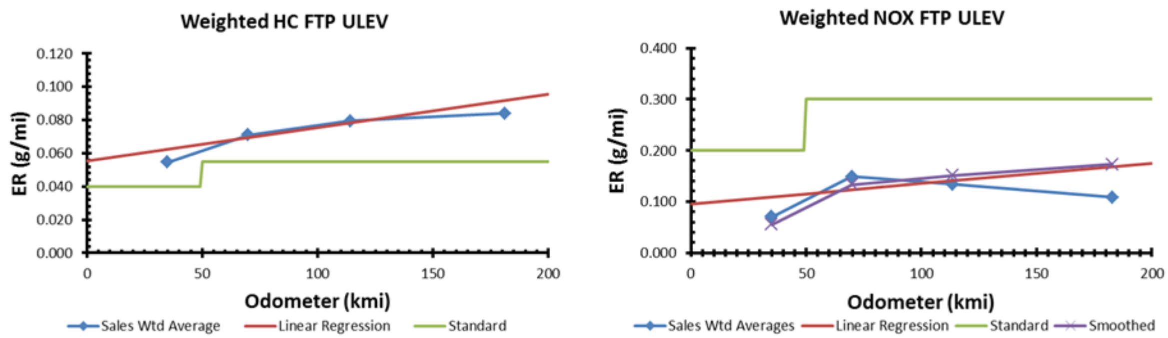
Due to relatively low sample size, sales-weighting was not done on these results. Additionally, cars tested under CARB's VSP were common models and considered representative of the fleet. Figure 4.3-14 show the fractions in the moderate and high emission regimes. The individual points are the actual data and the lines are smoothed representations, since there were few data points.

Figure 4.3-14: Unweighted regime fractions for moderate and high emission regimes as a function of vehicle mileage (odometer)



As shown in Figure 4.3-14, it is worth mentioning for HC emissions that between 45 and 50 percent of cars were found to exceed the standard and about 20 percent of cars exceeded twice the standard. Figure 4.3-15 shows the resulting products of regime fractions and FTP based emission factors derived from VSP data. The blue points are the average emissions for each odometer bin, the red line is the least-squares regression line for the clouds in Figure 4.3-13, and the green line represents the 50,000 and 100,000-mi standard for ULEVs. For NO_X, the purple line is the average emission rate using smoothed regime fractions.

Figure 4.3-15: Weighted average FTP emission rates (g/mi) as a function of vehicle mileage (odometer)

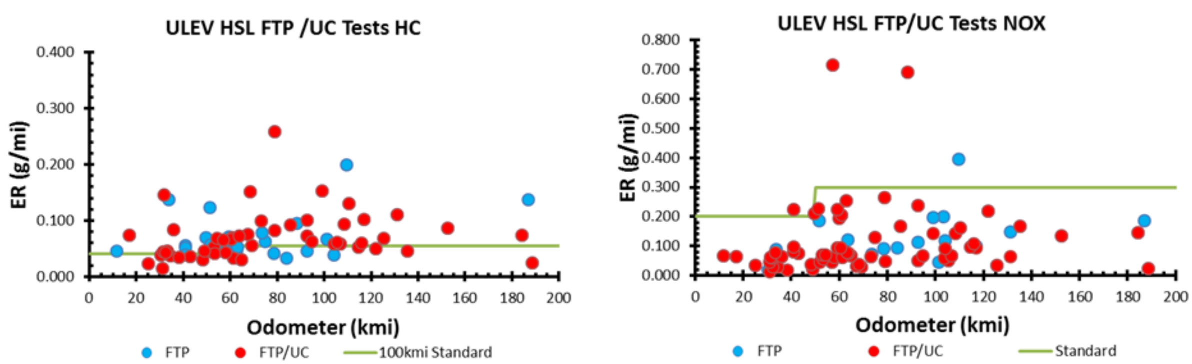


For NO_X, the average emission rates almost match the linear regression line, and are well below the 50,000 and 100,000-mi standard. Results for HC were above the standards.

4.3.1.1.9.3. UC RESULTS OF HIGH, MODERATE, NORMAL FTP REGIMES

In order to calculate UC based emission rates, both FTP and UC emission data from the same vehicles were needed. There are a total of 75 FTP tests where only 52 tests from cars that underwent both FTP and UC tests. The cars are first categorized as high, moderate, or normal regimes based on their FTP results. Then, the average emission rate values are gathered for the UC test by regime. In doing so, it is assumed that a high-emission-regime test under the FTP will also be a high-emitter under the UC test. Figure 4.3-16 shows the NO_X and HC FTP composite emissions rates (g/mi) with the blue circles, and the red circles are data points for vehicles that have both FTP and UC tests.

Figure 4.3-16: FTP test results for ULEV vehicles tested under CARB VSP program.



As shown in Figure 4.3-16, most of the tests were both FTP and UC tests. For HC, most results were above the standard, and were about the same as for the L2ULEV level. For NO_X, most points were below the standard, and much more loosely grouped than L2ULEV. The average values for the UC results corresponding to those tests by regime and bag are listed in Tables 4.3-13, 4.3-14 and 4.3-15 below.

Table 4.3-13: ULEV HC Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High	8	>0.110	1.113**	0.032**	0.092**
Moderate	27	0.055 to 0.110	0.773	0.022	0.050
Normal	17	<0.055*	0.407	0.012	0.022

*Useful Life Certification Standard.

**Original values were less than lower regimes. Interpolated or extrapolated values were substituted.

Table 4.3-14: ULEV NO_X Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High		>0.600	0.580**	0.085**	0.170**
Moderate		0.300 to 0.600	0.580**	0.085**	0.170**
Normal	52	<0.300*	0.580	0.085	0.170

*Useful Life Certification Standard

**No observations in moderate or high. Normal values were substituted.

Table 4.3-15: ULEV CO Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High	1	>8.4	19.6**	5.1	7.3
Moderate	4	4.2 to 8.4	19.6	3.3	2.5
Normal	46	<4.2*	6.2	0.9	0.6

*Useful Life Certification Standard

**Original value was less than lower regime's. Moderate value was substituted.

In Table 4.3-13 for HC, the observations are well distributed among the three emission regimes. However, the level for UC Bag 2 Moderate was originally less than the Normal value, and the value for UC Bag 3 High was very low. So, the original values were extrapolated from the Moderate levels. In Table 4.3-14, for NO_X, there were no observations in the Moderate or High regimes among the 52 cars with both FTP and UC tests. The Moderate and High regimes were populated with the values from the Normal Regime. This makes the emission rates invariant with odometer.

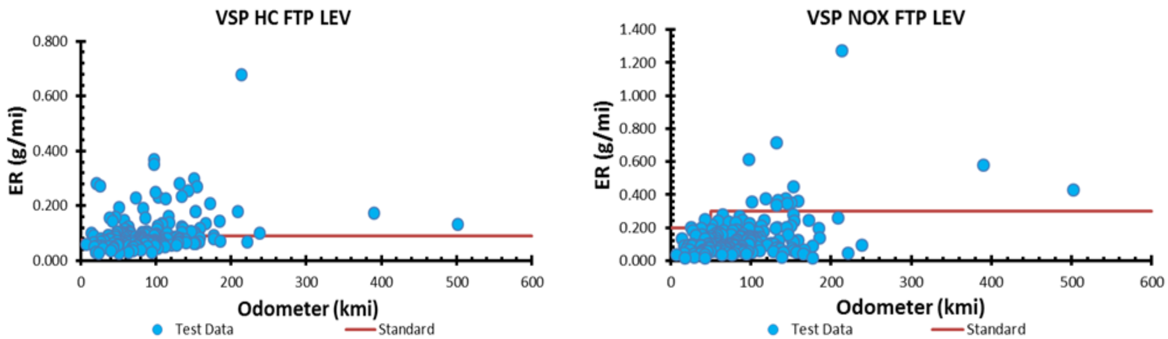
4.3.1.1.10. LEV

Low Emission Vehicle (LEV) is the least stringent emission category identified under the LEV program. LEV vehicles have intermediate (50,000 miles/5 years) NMOG and NO_X standards of 0.075 and 0.2 g/mi, and full useful-life (100,000 miles/10 years) NMOG and NO_X standards of 0.090 and 0.3 g/mi. To update base emission rates for LEVs, staff followed similar steps as described earlier for LEV I ULEVs.

4.3.1.1.10.1. FTP RESULTS

Figure 4.3-17 shows the universe of FTP composite emission rates versus odometer for LEV cars from HSL research and surveillance data. There are 181 data points. This figure also shows the NO_X and NMOG 50,000-mi and 100,000-mi standards. Below the red line is the normal emission regime; above are the Moderate and High emission regimes.

Figure 4.3-17: VSP HC and NO_X FTP Composite emission rates (g/mi) vs. Vehicle Mileage (Odometer)

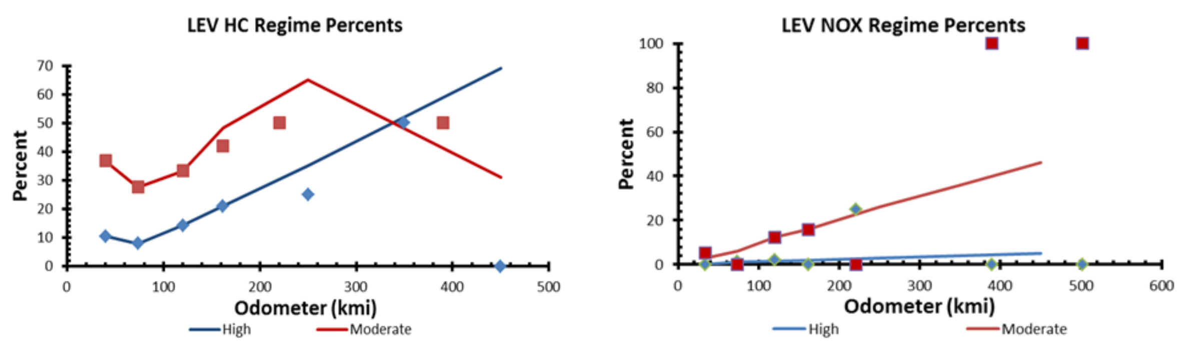


For HC most of the points are above the standard. For NO_X, very few points fell above the standard.

4.3.1.1.10.2. SALES WEIGHTING, REGIME FRACTIONS

Due to relatively low sample size, emission results were not weighted averaged using sales data. Additionally, cars tested under CARB's VSP were chosen in proportions representative of the fleet. Figure 4.3-18 shows the fractions in the moderate and high emission regimes. The individual points are the actual data and the lines are smoothed representations, since there are few data points. For HC, the High regime fractions were extrapolated to rise quickly. This assumption required the Moderate regime fractions to peak and fall with odometer in order to add to 100 percent.

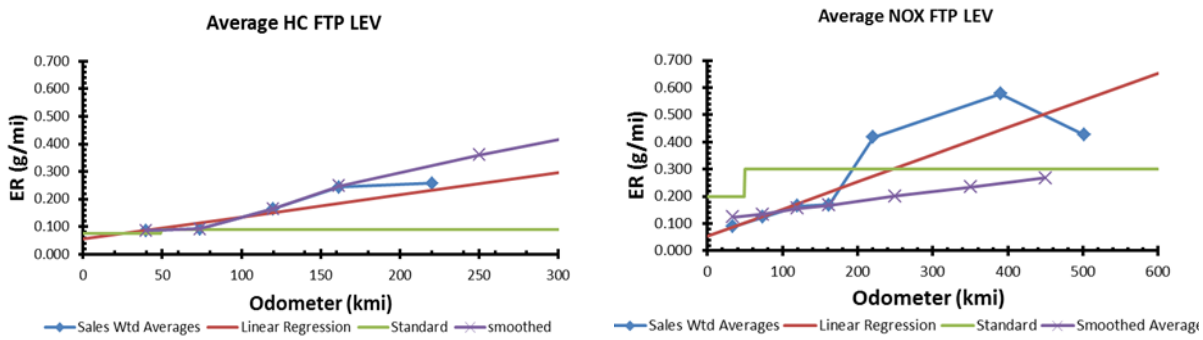
Figure 4.3-18: Unweighted regime fractions for moderate and high emission regimes as a function of vehicle mileage (odometer)



It is worth mentioning for HC emissions that between 30 and 70 percent of cars were found to exceed the standard and about 20-50 percent of cars exceeded twice the standard.

Figure 4.3-19 shows the resulting products of regime fractions and FTP-based emission factors derived from VSP data. The blue points are the average emissions for each odometer bin. The purple line is the average emissions for the smoothed regime fractions. The red line is the least-squares regression line for the clouds in Figure 4.3-17. The green line represents the 50,000- and 100,000-mi standard for ULEVs.

Figure 4.3-19: Weighted average FTP emission rates (g/mi) as a function of vehicle mileage (odometer)

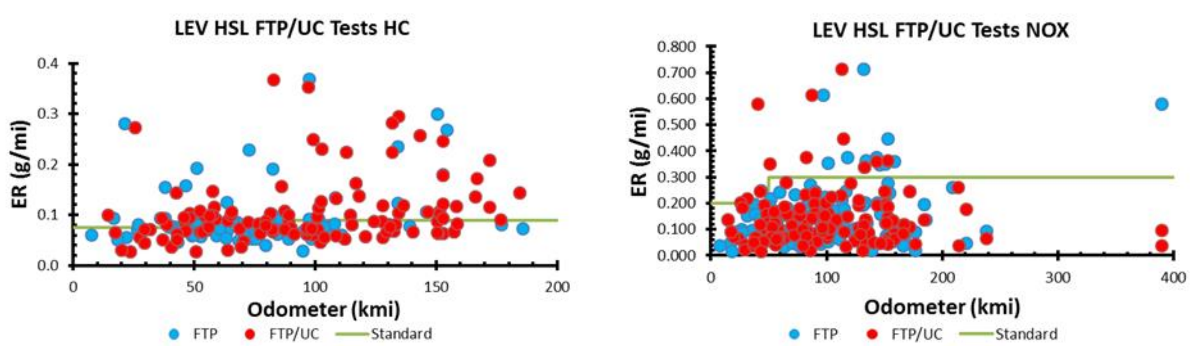


For HC, the smoothed average emission rates extrapolate better, and are well above the linear regression line. For NO_X, the smoothed average emission rates have a smoother trend with odometer, and are below the linear regression line. For HC, the average for all odometers was above the standard. For NO_X the average crossed the standard line at about 250,000 mi odometer.

4.3.1.1.10.3. UC RESULTS OF HIGH, MODERATE, NORMAL FTP REGIMES

Similar to ULEVs, in order to calculate UC based emission rates, both FTP and UC emission data from same vehicles were needed. There are 181 FTP tests of which 130 tests are associated with cars that have undergone both FTP and UC tests. Figure 4.3-20 shows the NO_X and HC FTP composite emissions rates (g/mi) in blue and in red are data points for vehicles that have both FTP and UC tests.

Figure 4.3-20: FTP test results for LEV vehicles tested under CARB VSP program.



As shown in Figure 4.3-20, most of the cars with FTP data also underwent UC tests. Many of the HC points and NO_X points were above the standards. The average values for the UC results corresponding to those tests by regime and bag are listed in Tables 4.3-16, 4.3-17, and 4.3-18 below.

Table 4.3-16 LEV HC Mean Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High	16	>0.180	1.853	0.134	0.504
Moderate	44	0.090 to 0.180	1.188	0.031	0.099
Normal	70	<0.090*	0.822	0.024	0.064

*Useful Life Certification Standard.

Table 4.3-17: LEV NO_X Mean Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High	3	>0.600	1.852	0.792	1.283
Moderate	7	0.300 to 0.600	1.319	0.351	0.635
Normal	120	<0.300*	0.846	0.118	0.247

*Useful Life Certification Standard

Table 4.3-18: LEV CO Mean Regime Values

Regime	Sample size	FTP Range, g/mi	UC Bag 1	UC Bag 2	UC Bag 3
High	1	>8.4	20.3**	10.7	14.6
Moderate	3	4.2 to 8.4	20.3	3.6	8.6
Normal	125	<4.2*	10.5	2.1	2.0

*Useful Life Certification Standard

**Original value was less than Moderate level. Moderate value was substituted.

In Table 4.3-18 for CO, there were relatively few Moderate and High observations. The Moderate regime value for UC Bag 1 was higher than the High regime value. The High regime had only one observation. The moderate value was substituted for this one value. It makes little contribution to the totals since the high regime fractions are very small.

4.3.1.1.11. PRE-LEV CATEGORIES

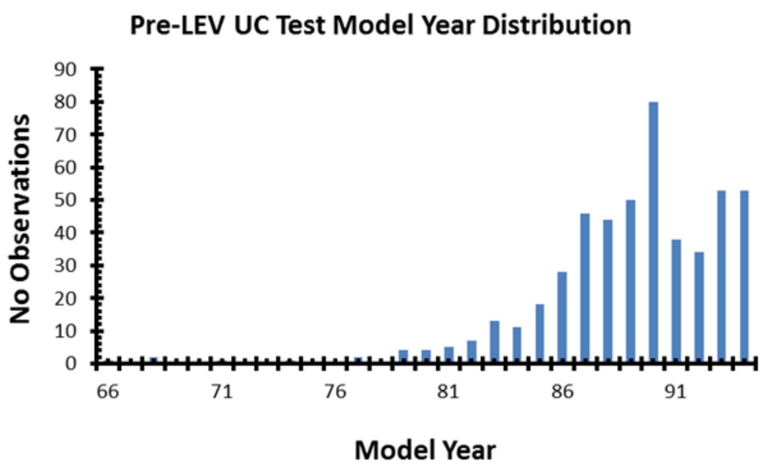
Below is presented the analysis of the remaining model years (1985 – 1993) data. In the absence of any IUVP data, the UC tests from the VSP were used to update emission rates from these vehicles. The procedure is similar to LEVs and ULEVs described earlier, however, the populations of many different standards groups were amalgamated into one “fleet” number, and there was no segregation by emission regime. This fleet composition changes with calendar year of observation. The emissions were correlated by odometer, but emissions as a function of odometer could not be directly compared to the fleet standard; this is because the standard is a function of model year. As a result, the following steps were taken to update emissions rates for Pre-1994 vehicles in EMFAC model:

1. Gather the UC results for pre-LEVs.
2. Determine the average emission rates vs odometer relationship for the UC data.

4.3.1.1.11.1. MODEL YEAR DISTRIBUTION

From the VSP, we were able to collect UC emission data for 311 pre-LEV vehicles. It needs to be mentioned that some of these test data were collected during the late 1990s and were incorporated as part of EMFAC2000 updates. About half of the dataset was collected between 2000 and 2003. Figure 4.3-21 shows the frequency distribution of model years for the Pre-LEV vehicles tested.

Figure 4.3-21: Model year distribution for pre-LEV vehicles tested under CARB's VSP



As shown in Figure 4.3-21, the range of vehicle model years is from 1966 to 1994, with the majority of the population lying within the 1985 – 1990 and 1991 – 1994 model year bins.

There were 8 tests from 1970s model years and 40 tests from 1980 to 1984 model years. In order to make the emission correlations for this lumped category more robust, it was decided to drop the non-catalyst vehicles (the 1960 and 1970s vehicles) and the carbureted vehicles (the 1980 to 1984 vehicles) from the correlations. Further removing duplicate tests left 263 data points.

4.3.1.1.11.2. UC DATA

Figures 4.3-22 and 4.3-23 show the universe of UC emission rates (total of 263 tests) versus odometer for pre-LEV cars tested under CARB's VSP. Additionally, the figures show the least-squares regressions for the emissions vs odometer.

Figure 4.3-22: VSP HC UC Bag 1 and Bag 2 emission rates (g/mi) vs. Vehicle Mileage (Odometer)

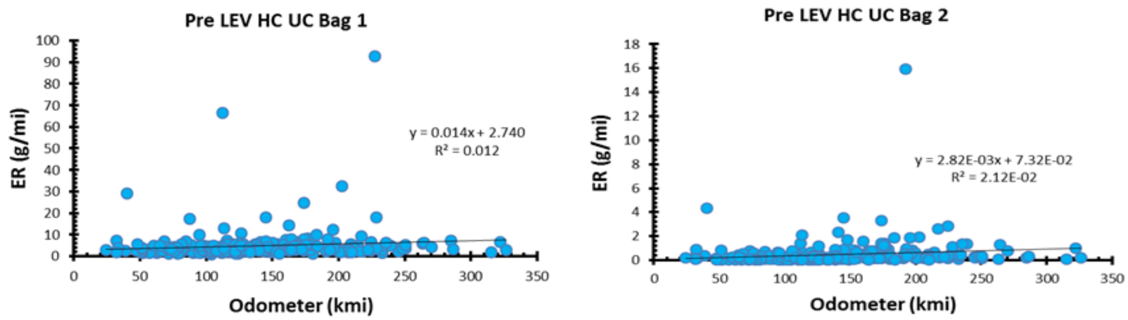
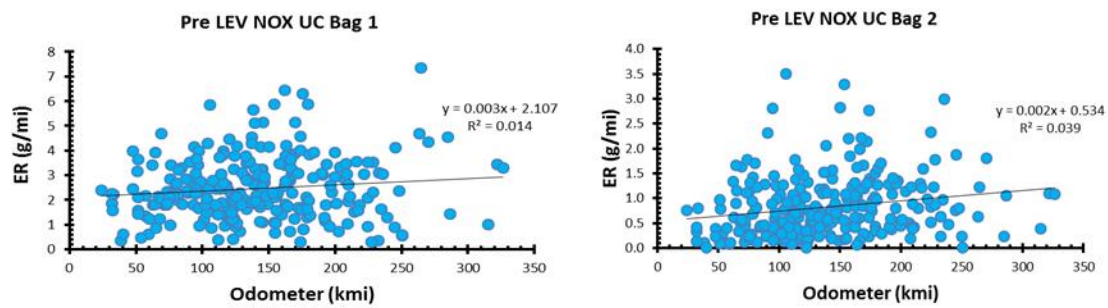


Figure 4.3-23: VSP NO_X UC Bag 1 and Bag 2 emission rates (g/mi) vs. Vehicle Mileage (Odometer)



The least squares lines have very low correlation coefficients, mainly because of the spread of the data. As a result, the emission rates were averaged on odometer ranges.

4.3.1.1.11.3. UC RESULTS

UC based pre-LEV emission data from CARB's VSP were averaged over 50,000-mi odometer-bins for UC bags 1 through 3. Figures 4.3-24 to 4.3-26 show the average UC-based emission rates by odometer bin for HC, CO and NO_X.

Figure 4.3-24: Average HC emission rates (g/mi) for UC Bags 1, 2, and 3 as a function of Vehicle Mileage (Odometer)

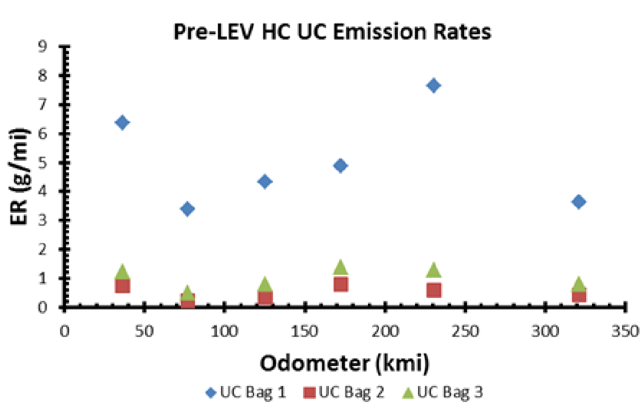


Figure 4.3-25: Average CO emission rates (g/mi) for UC Bags 1, 2, and 3 as a function of Vehicle Mileage (Odometer)

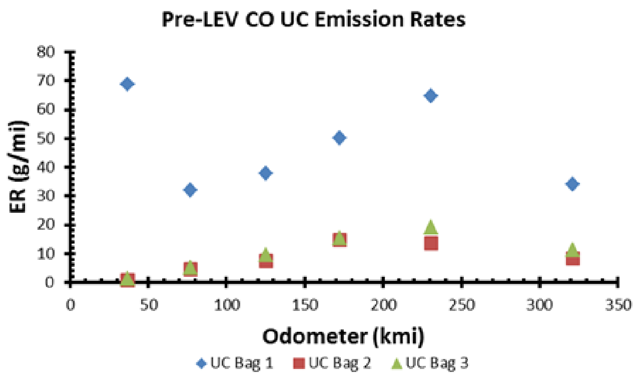
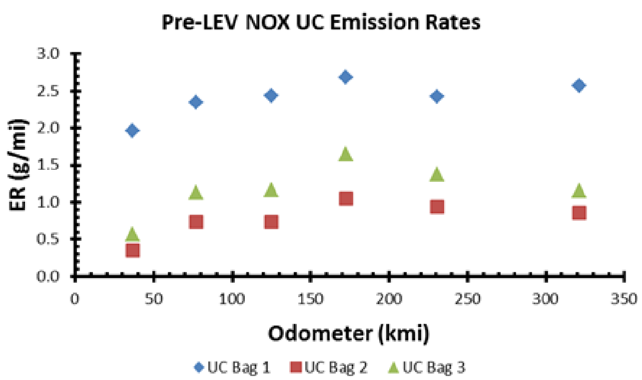


Figure 4.3-26: Average NOx emission rates (g/mi) for UC Bag 1, 2, and 3 as a function of Vehicle Mileage (Odometer)



In order to model emission rates for 1985-1993 model year vehicles in EMFAC, staff used regression modeling techniques to find the best fit that explains the data. Since there were relatively few readings above the 250,000-mi bin and within 0 to 50,000-mi bin, curves were fitted only in the 50 to 250 kmi-range. Fitted results are shown in Figures 4.3-27 to 4.3-29.

Figure 4.3-27: Modeled HC emission rates (g/mi) for UC Bags 1, 2, and 3 as a function of Vehicle Mileage (Odometer)

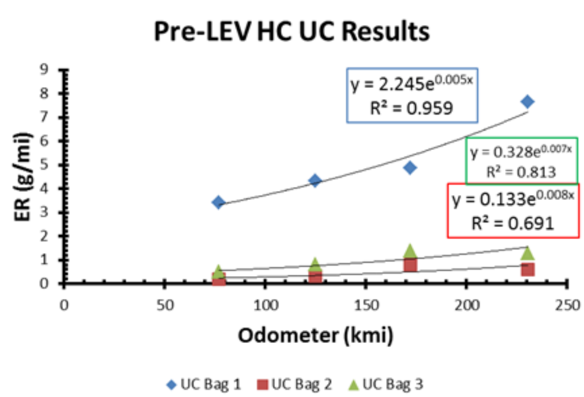


Figure 4.3-28: Modeled CO emission rates (g/mi) for UC Bags 1, 2, and 3 as a function of Vehicle Mileage (Odometer)

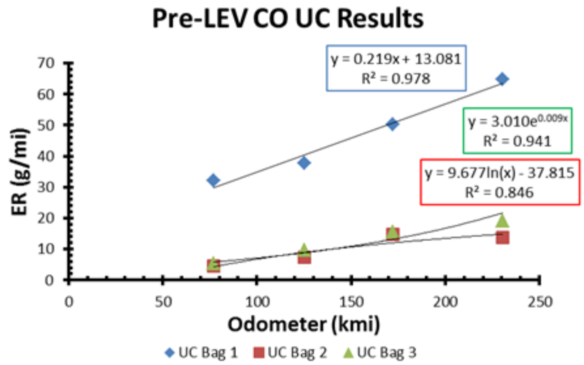
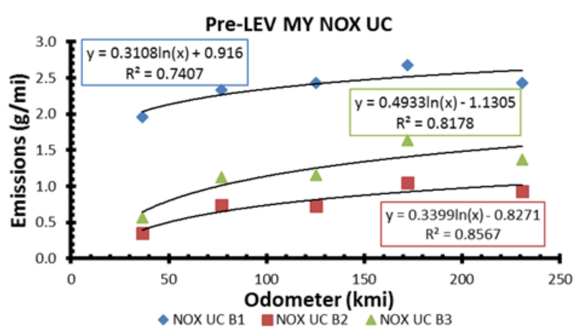


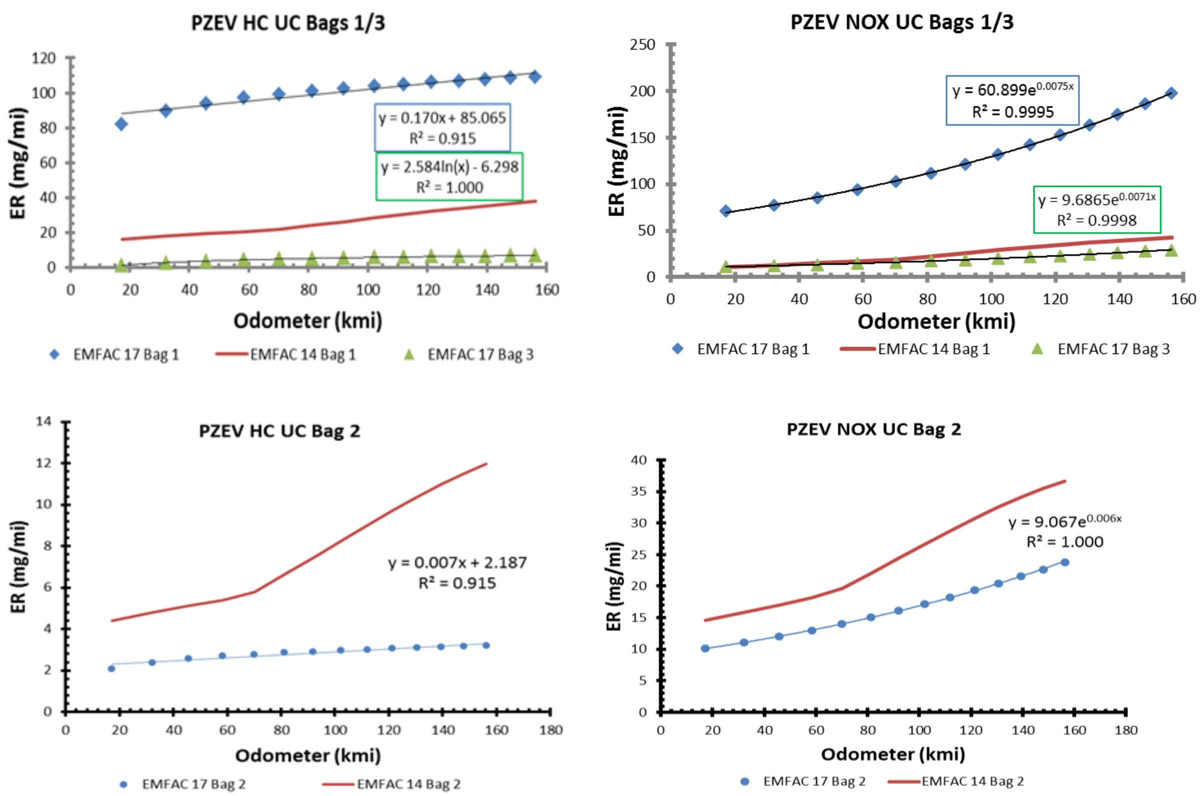
Figure 4.3-29: Modeled NOx emission rates (g/mi) for UC Bags 1, 2, and 3 as a function of Vehicle Mileage (Odometer)



4.3.1.1.12. RESULTS OF ANALYSIS

As part of the EMFAC2017 model implementation, emission rates are modeled in the form of regression equations with vehicle mileage (odometer—in units of 10,000 miles) as an input to the model. Therefore, in order to implement findings from this analysis into the EMFAC2017 model, staff needed to translate regime-based emission rates into weighted-average emission rates. To do this, staff curve fitted the regime fractions as a function of odometer, and calculated the combined emission rates for each bag of the UC for different odometers using equation 4.3-3. The resulting emission rates were again fitted with regressions as a function of odometer, and these fitted emission rates will be used in the model. Following are some comparisons between the EMFAC17 emission rates and the emission factors from EMFAC2014.

Figure 4.3-30: UC Bags 1- 3 HC and NO_X emission rates (g/mi) for PZEVs – EMFAC2014 vs. EMFAC2017



UC Bag 3 results for EMFAC2014 were not shown because previous to EMFAC2017 UC Bag 3 values were not used in the emission calculations. Start values were corrected from UC Bag 1 only. For PZEVs the running emissions for HC are less than those in EMFAC 2014 and do not increase as much with odometer, but the start emissions are much higher. For PZEV NO_X emissions, rates of increase of emissions with odometer are the same as or higher than EMFAC2014, and the start emissions are significantly higher.

The L2ULEVs have higher bag 1 and lower bag 2 emissions than EMFAC2014. EMFAC2017 emission rates are approximately invariant with odometer as the IUVP data had very few emission data points in the Moderate and High regimes.

Figure 4.3-31: UC Bags 1- 3 HC and NOx emission rates (g/mi) for L2ULEVs – EMFAC2014 vs. EMFAC2017

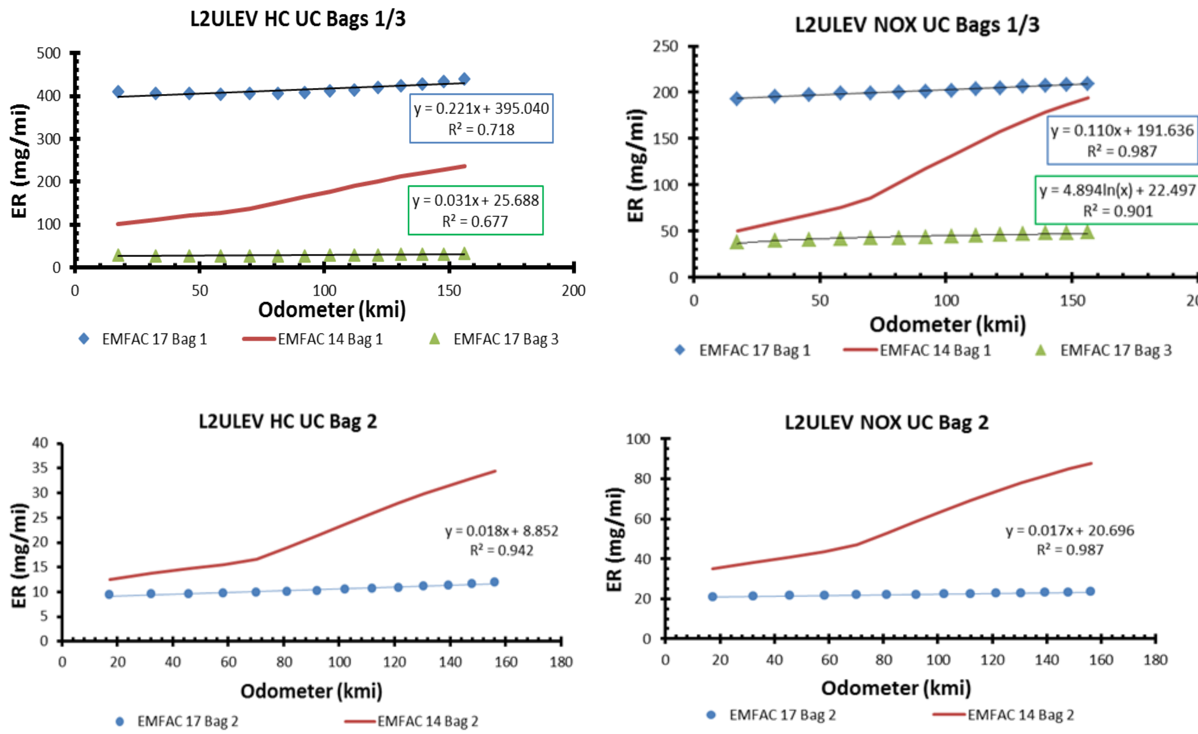
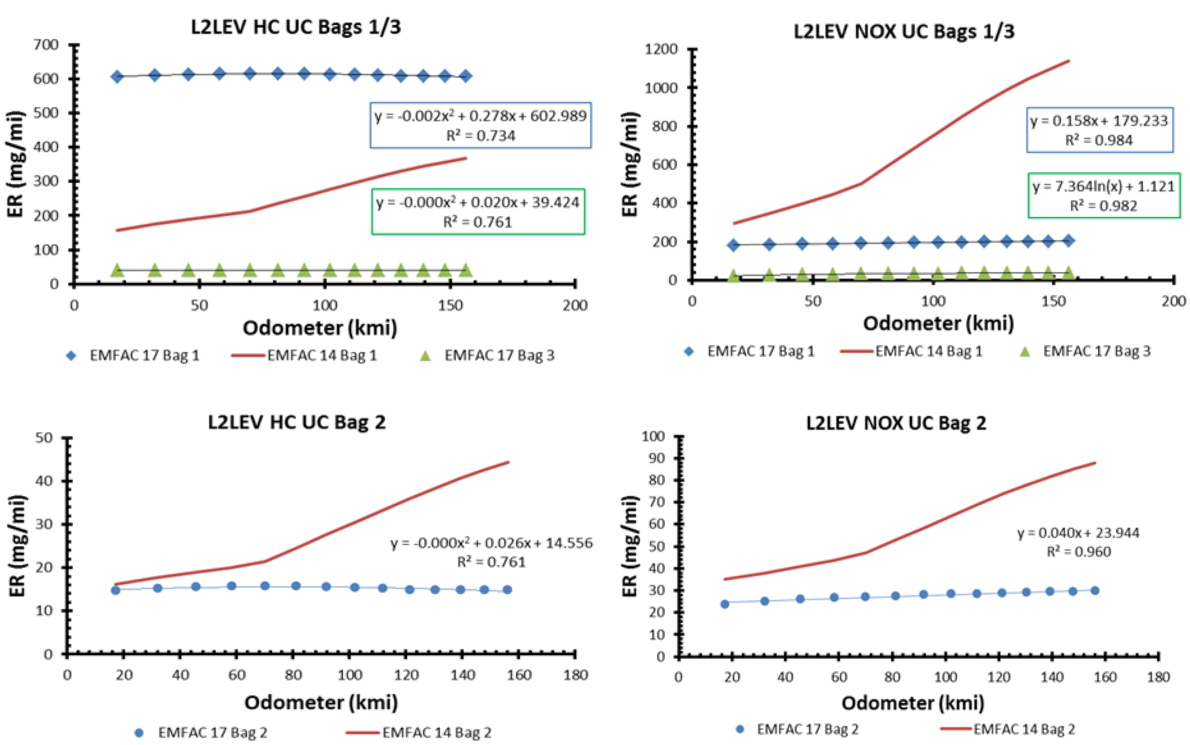
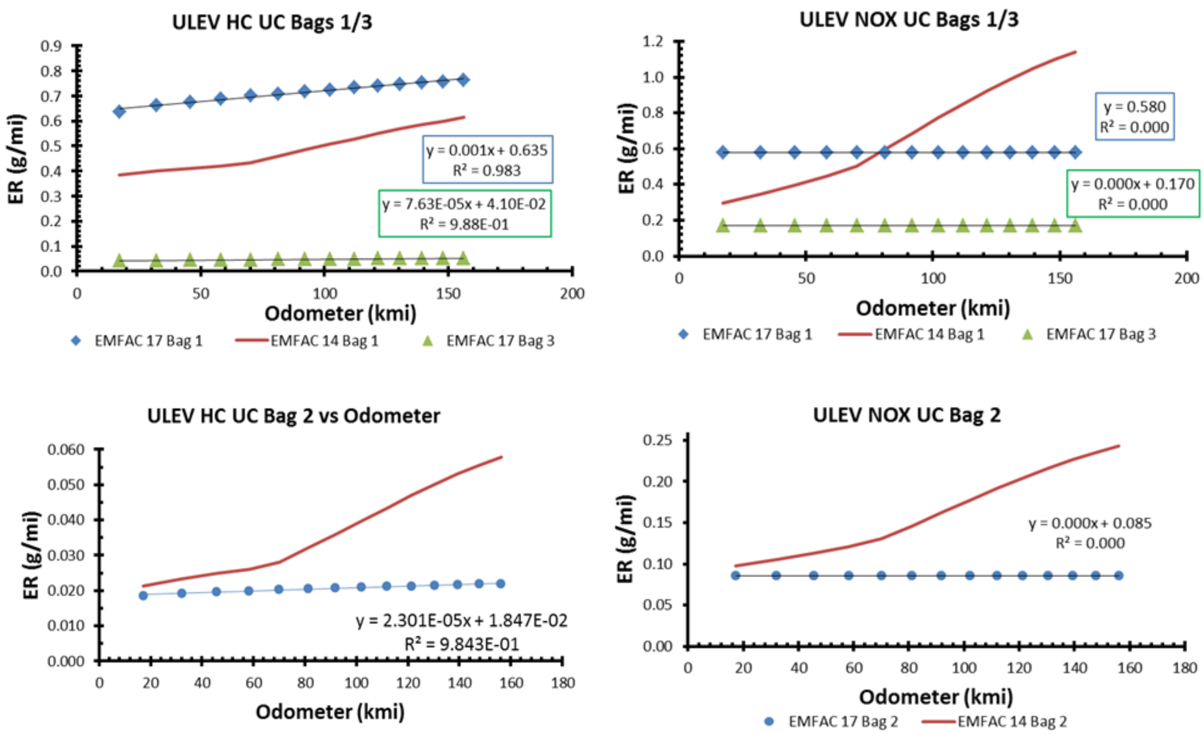


Figure 4.3-32: UC Bags 1- 3 HC and NOx emission rates (g/mi) for L2LEVs – EMFAC2014 vs. EMFAC2017



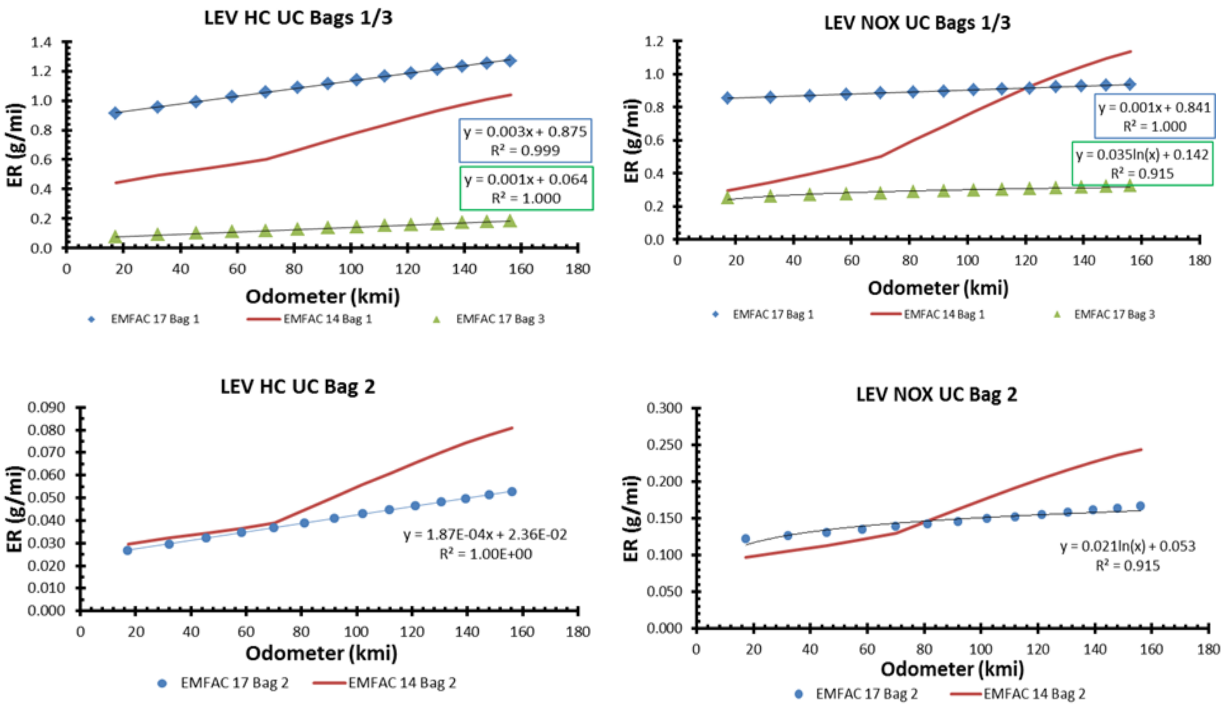
The analysis for L2LEVs showed that emissions do not increase significantly with odometer. For NO_X, EMFAC2017 emission rates for both the bag 1 and bag 2 are below those of the EMFAC2014 model.

Figure 4.3-33: UC Bags 1- 3 HC and NO_X emission rates (g/mi) for ULEVs – EMFAC2014 vs. EMFAC2017



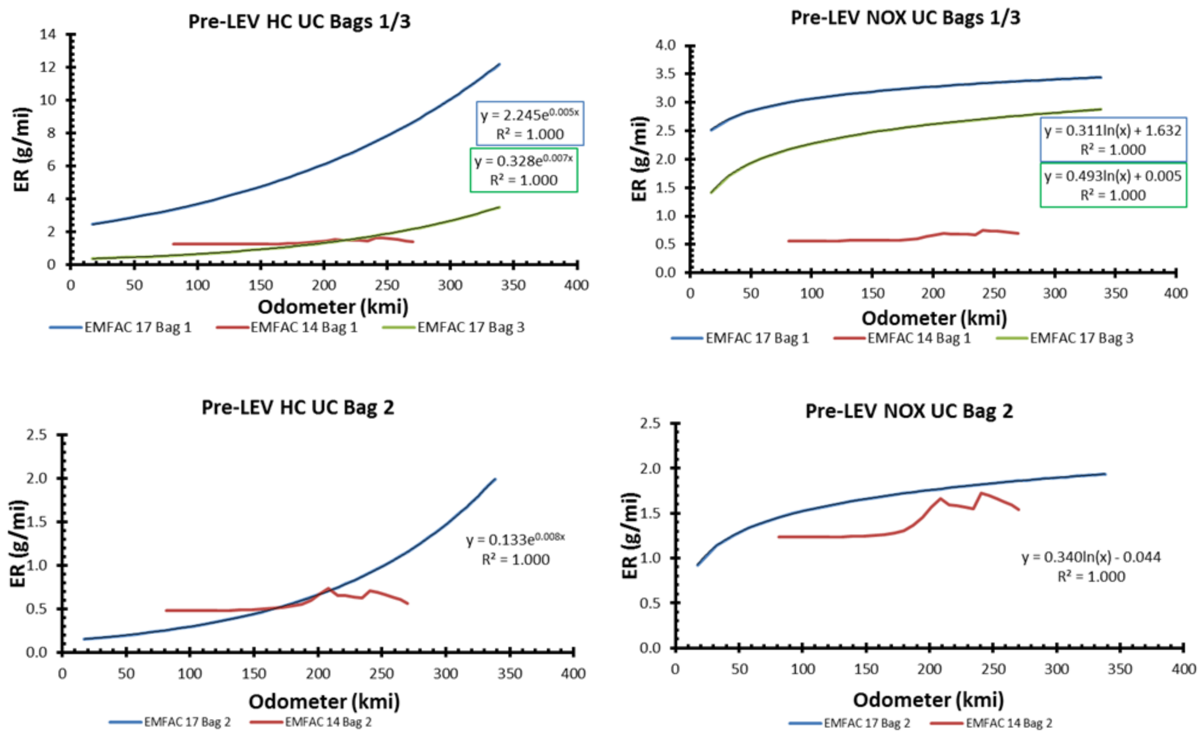
For ULEVs HC emissions for Bag 1 have a quite noticeable slope (i.e., rate of increase in emission with respect to odometer). EMFAC2017 Bag 2 emissions have a positive slope with odometer, but less than the EMFAC2014 value. ULEVs exhibited high numbers of observations above the standards for NMOG, which led to much higher emissions than L2LEVs. On the other side, NO_X results do not show any significant increase with odometer. This is because the UC tests to determine the emission regime boundaries showed no Moderate or High NO_X results.

Figure 4.3-34: UC Bags 1- 3 HC and NO_X emission rates (g/mi) for LEVs – EMFAC2014 vs. EMFAC2017



For the LEVs, slopes were all non-zero, but smaller than those of EMFAC2014. In EMFAC2014, there was a high-emitter phase-in at about 70,000 mi odometer, which is the source of the change in slopes. For the EMFAC2017 curves, both the Bag 2 values for HC and NO_X are higher than the EMFAC2014 counterparts. Figure 4.3-35 shows the results for the combined 1985 – 1993 model year LDVs on the UC cycle. The blue and green curves are the EMFAC2017 values. The red curves are the existing EMFAC2014 UC Bag 1 and Bag 2 values evaluated for the 1985 – 1993 model years.

Figure 4.3-35: UC Bags 1- 3 HC and NO_X emission rates (g/mi) for Pre-LEVs – EMFAC2014 vs. EMFAC2017



For the Pre-LEVs the UC Bag 2 emission rates for EMFAC2017 have a much greater dependence on odometer than the EMFAC2014 emission rates for both NO_X and HC. The EMFAC2017 UC Bag 1 emissions are higher than EMFAC2014 by a factor of 3 to 10.

4.3.1.1.13. SUMMARY OF RESULTS

The data analysis to develop the UC_{P1}, UC_{P2}, and UC_{P3}, (corresponding to Bag 1 through Bag 3) BERs involved splitting the IUVP-tested vehicles into different groups based upon their odometer reading (50 kmi bins) and their emission certification standards (LEV1 LEV, LEV2 SULEV, etc.). Within these groups, the vehicles were segregated further using their IUVP-measured composite FTP ERs. Vehicles were split into three separate regimes: normal emitters, which emitted at or below the certification standard; moderate emitters, which emitted above the standard, but at or below 2x the standard; and high emitters, which emitted above 2x the standard. The vehicles falling within each of the three regimes were counted, and the counts were adjusted using a sales-weighting procedure. “Regime Fractions” (the percentages of vehicles falling within each of the regimes) were computed. The sales-weighting was performed using California vehicle engine family sales data, gathered by CARB through Certification.

Test data, from CARB’s VSP, were then used to derive the UC ERs of vehicles falling within the three regimes. First, vehicles possessing both FTP and UC test results were identified in the VSP database. These vehicles were segregated by odometer range, and the California certification standard they certified to. They were then further segregated into normal, moderate, and high emission regimes using their composite FTP results. Once segregated, average UC_{P1}, UC_{P2}, and UC_{P3} ERs were determined for each regime. The regimes were then merged to compute BERs for $UC_{P1,}$ UC_{P2}, and UC_{P3}, as a function of odometer, according to Equation 3.4-3.

Tables 4.3-19 to 4.3-30 below provide the regression equations to be utilized in EMFAC2017 for LD Base Emission Rates (BERs). They are listed by Tech Group IDs – Numerical identifiers for technology groups in the EMFAC model. The correlations are in units of g/mi for pollutants and 10 kmi for odometer.

Table 4.3-19: Tech Group 23 (L1LEV) BER Correlation Coefficients

	TG	Process	Pollutant	A	B	C	Regression_ID
L1 LEV	23	UC1	HC	0.02574	0.8751		Linear
L1 LEV	23	UC1	NO_X	0.006119	0.8415		Linear
L1 LEV	23	UC1	CO	0.1022	10.57		Linear
L1 LEV	23	UC2	HC	0.001874	0.02358		Linear
L1 LEV	23	UC2	NO_X	0.02116	0.102		Log Linear
L1 LEV	23	UC2	CO	0.04157	1.995		Linear
L1 LEV	23	UC3	HC	0.007665	0.06406		Linear
L1 LEV	23	UC3	NO_X	0.03452	0.2213		Log Linear
L1 LEV	23	UC3	CO	0.571	1.5779		Log Linear

Table 4.3-20: Tech Group 24 (L1ULEV) BER Correlation Coefficients

	TG	Process	Pollutant	A	B	C	Regression_ID
L1 ULEV	24	UC1	HC	0.008533	6.35E-01		Linear
L1 ULEV	24	UC1	NO_X		0.578		Linear
L1 ULEV	24	UC1	CO	1.30	5.2366		Log Linear
L1 ULEV	24	UC2	HC	0.00023	1.85E-02		Linear
L1 ULEV	24	UC2	NO_X		0.085		Linear
L1 ULEV	24	UC2	CO	0.2724	0.644		Log Linear
L1 ULEV	24	UC3	HC	7.63E-04	4.10E-02		Linear
L1 ULEV	24	UC3	NO_X		0.1695		Linear
L1 ULEV	24	UC3	CO	0.4433	1.7899		Log Linear

Table 4.3-21: Tech Group 28 (L2LEV) BER Correlation Coefficients

	TG	Process	Pollutant	A	B	C	Regression_ID
L2 LEV	28	UC1	HC	-1.67E-04	2.78E-03	0.603	quadratic
L2 LEV	28	UC1	NO_X	1.579E-03	0.17923		Linear
L2 LEV	28	UC1	CO		8.327		Linear
L2 LEV	28	UC2	HC	-1.700E-05	2.618E-04	0.01456	quadratic
L2 LEV	28	UC2	NO_X	4.020E-04	2.394E-02		Linear
L2 LEV	28	UC2	CO		1.129		Linear
L2 LEV	28	UC3	HC	-1.31E-05	2.01E-04	3.94E-02	quadratic
L2 LEV	28	UC3	NO_X	7.364E-03	1.808E-02		Log Linear
L2 LEV	28	UC3	CO		1.333		Linear

Table 4.3-22: Tech Group 29 (L2ULEV) BER Correlation Coefficients

	TG	Process	Pollutant	A	B	C	Regression_ID
L2 ULEV	29	UC1	HC	2.866E-03	3.980E-01		Linear
L2 ULEV	29	UC1	NO_X	1.100E-03	1.914E-01		Linear
L2 ULEV	29	UC1	CO	0.016	4.5876		Linear
L2 ULEV	29	UC2	HC	1.770E-04	8.852E-03		Linear
L2 ULEV	29	UC2	NO_X	1.700E-04	2.070E-02		Linear
L2 ULEV	29	UC2	CO	0.003	0.5591		Linear
L2 ULEV	29	UC3	HC	3.208E-04	2.578E-02		Linear
L2 ULEV	29	UC3	NO_X	4.894E-03	3.377E-02		Log Linear
L2 ULEV	29	UC3	CO	0.5654	0.007		Exponential

Table 4.3-23: Tech Group 31 (L2PZEV) BER Correlation Coefficients

	TG	Process	Pollutant	A	B	C	Regression_ID
L2 PZEV	31	UC1	HC	1.698E-03	8.507E-02		Linear
L2 PZEV	31	UC1	NO_X	6.090E-02	7.550E-02		Exponential
L2 PZEV	31	UC1	CO	-6.03E-04	2.520E-02	1.868E+00	quadratic
L2 PZEV	31	UC2	HC	7.000E-05	2.187E-03		Linear
L2 PZEV	31	UC2	NO_X	9.087E-03	6.000E-02		Exponential
L2 PZEV	31	UC2	CO	-8.07E-05	3.373E-03	4.134E-01	quadratic
L2 PZEV	31	UC3	HC	2.584E-03	-3.479E-04		Log Linear
L2 PZEV	31	UC3	NO_X	9.687E-03	7.000E-02		Exponential
L2 PZEV	31	UC3	CO	-3.089E-04	1.292E-02	3.601E-01	quadratic

Table 4.3-24: Tech Group 38 (L3SULEV 20) BER Correlation Coefficients

	TG	Process	Pollutant	A	B	C	Regression_ID
L3 SULEV 20	38	UC1	HC	1.132E-03	5.671E-02		Linear
L3 SULEV 20	38	UC1	NO_X	4.060E-02	7.550E-02		Exponential
L3 SULEV 20	38	UC1	CO	-6.025E-04	2.520E-02	1.868E+00	quadratic
L3 SULEV 20	38	UC2	HC	4.667E-05	1.458E-03		Linear
L3 SULEV 20	38	UC2	NO_X	6.058E-03	6.000E-02		Exponential
L3 SULEV 20	38	UC2	CO	-8.065E-05	3.373E-03	4.134E-01	quadratic
L3 SULEV 20	38	UC3	HC	1.723E-03	-2.319E-04		Log Linear
L3 SULEV 20	38	UC3	NO_X	6.458E-03	7.000E-02		Exponential
L3 SULEV 20	38	UC3	CO	-3.089E-04	1.292E-02	3.601E-01	quadratic

Table 4.3-25: Tech Group 39 (L3ULEV 50) BER Correlation Coefficients

	TG	Process	Pollutant	A	B	C	Regression_ID
L3 ULEV 50	39	UC1	HC	1.146E-03	1.592E-01		Linear
L3 ULEV 50	39	UC1	NO_X	4.400E-04	7.654E-02		Linear
L3 ULEV 50	39	UC1	CO	1.295E-02	3.714E+00		Linear
L3 ULEV 50	39	UC2	HC	7.080E-05	3.541E-03		Linear
L3 ULEV 50	39	UC2	NO_X	6.800E-05	8.278E-03		Linear
L3 ULEV 50	39	UC2	CO	2.429E-03	4.526E-01		Linear
L3 ULEV 50	39	UC3	HC	1.283E-04	1.031E-02		Linear
L3 ULEV 50	39	UC3	NO_X	1.958E-03	1.351E-02		Log Linear
L3 ULEV 50	39	UC3	CO	4.577E-01	7.000E-03		exponential

Table 4.3-26: Tech Group 44 (L3ULEV70) BER Correlation Coefficients

	TG	Process	Pollutant	A	B	C	Regression_ID
L3 ULEV 70	44	UC1	HC	1.605E-03	2.229E-01		Linear
L3 ULEV 70	44	UC1	NO_X	6.160E-04	1.072E-01		Linear
L3 ULEV 70	44	UC1	CO	1.295E-02	3.714E+00		Linear
L3 ULEV 70	44	UC2	HC	9.912E-05	4.957E-03		Linear
L3 ULEV 70	44	UC2	NO_X	9.520E-05	1.159E-02		Linear
L3 ULEV 70	44	UC2	CO	2.429E-03	4.526E-01		Linear
L3 ULEV 70	44	UC3	HC	1.796E-04	1.444E-02		Linear
L3 ULEV 70	44	UC3	NO_X	2.741E-03	1.891E-02		Log Linear
L3 ULEV 70	44	UC3	CO	4.577E-01	7.000E-03		exponential

Table 4.3-27: Tech Group 45 (L3SULEV 30) BER Correlation Coefficients

	TG	Process	Pollutant	A	B	C	Regression_ID
L3 SULEV 30	45	UC1	HC	1.698E-03	8.507E-02		Linear
L3 SULEV 30	45	UC1	NO_X	6.090E-02	7.550E-02		Exponential
L3 SULEV 30	45	UC1	CO	-6.025E-04	2.520E-02	1.868E+00	quadratic
L3 SULEV 30	45	UC2	HC	7.000E-05	2.187E-03		Linear
L3 SULEV 30	45	UC2	NO_X	9.087E-03	6.000E-02		Exponential
L3 SULEV 30	45	UC2	CO	-8.065E-05	3.373E-03	4.134E-01	quadratic
L3 SULEV 30	45	UC3	HC	2.584E-03	-3.479E-04		Log Linear
L3 SULEV 30	45	UC3	NO_X	9.687E-03	7.000E-02		Exponential
L3 SULEV 30	45	UC3	CO	-3.089E-04	1.292E-02	3.601E-01	quadratic

Table 4.3-28: Tech Group 55 (L3ULEV 125) BER Correlation Coefficients

	TG	Process	Pollutant	A	B	C	Regression_ID
L3 ULEV 125	55	UC1	HC	2.866E-03	3.980E-01		Linear
L3 ULEV 125	55	UC1	NO_X	1.100E-03	1.914E-01		Linear
L3 ULEV 125	55	UC1	CO	1.295E-02	3.714E+00		Linear
L3 ULEV 125	55	UC2	HC	1.770E-04	8.852E-03		Linear
L3 ULEV 125	55	UC2	NO_X	1.700E-04	2.070E-02		Linear
L3 ULEV 125	55	UC2	CO	2.429E-03	4.526E-01		Linear
L3 ULEV 125	55	UC3	HC	3.208E-04	2.578E-02		Linear
L3 ULEV 125	55	UC3	NO_X	4.894E-03	3.377E-02		Log Linear
L3 ULEV 125	55	UC3	CO	4.577E-01	7.000E-03		exponential

Table 4.3-29: Tech Group 56 (L3LEV 160) BER Correlation Coefficients

	TG	Process	Pollutant	A	B	C	Regression_ID
L3 LEV 160	56	UC1	HC	-1.669E-04	2.776E-03	6.030E-01	quadratic
L3 LEV 160	56	UC1	NO_X	1.579E-03	1.792E-01		Linear
L3 LEV 160	56	UC1	CO		6.741		Linear
L3 LEV 160	56	UC2	HC	-1.700E-05	2.618E-04	1.456E-02	quadratic
L3 LEV 160	56	UC2	NO_X	4.020E-04	2.394E-02		Linear
L3 LEV 160	56	UC2	CO		0.914		Linear
L3 LEV 160	56	UC3	HC	-1.306E-05	2.012E-04	3.942E-02	quadratic
L3 LEV 160	56	UC3	NO_X	7.364E-03	1.808E-02		Log Linear
L3 LEV 160	56	UC3	CO		1.079		Linear

Table 4.3-30: Pre-LEV BER Correlation Coefficients

	TG	Process	Pollutant	A	B	C	Regression_ID
Pre-LEV		UC1	HC	2.25	5.00E-02		Exponential
Pre-LEV		UC1	NO_X	0.31	1.63E+00		Log Linear
Pre-LEV		UC1	CO	2.19	13.08		Log Linear
Pre-LEV		UC2	HC	0.13	8.00E-02		Exponential
Pre-LEV		UC2	NO_X	0.34	-4.40E-02		Log Linear
Pre-LEV		UC2	CO	9.68	-15.53		Log Linear
Pre-LEV		UC3	HC	0.33	7.00E-02		Exponential
Pre-LEV		UC3	NO_X	0.49	5.00E-03		Log Linear
Pre-LEV		UC3	CO	3.01	9.00E-02		Exponential

4.3.1.2. START EMISSIONS MODEL UPDATE

4.3.1.2.1. BACKGROUND

Starts emissions are the excess emissions that occur during and immediately after a vehicle's engine has been turned on. These emissions are in excess of normal running exhaust emissions. Starts emissions can arise from a vehicle's catalyst material not having achieved its optimal operating temperature, richer than normal air-to-fuel ratios, and other conditions associated with the start of the vehicle. A start is referred to as a 'cold start' when it occurs after the vehicle's engine has been off for 12 or more hours. The off-period is referred to as a 'soak period.' A start occurring after the vehicle's engine has been off fewer than 12 hours is referred to be a 'warm start.' The term 'hot start' is also sometimes used to describe starts that follow very short soak periods, such as 5 min.

Major updates have been incorporated into the modeling of start exhaust emissions (StE) of light-duty vehicles (LDV). For any LDV in EMFAC the LDV's cold start emission rates (StERs) are now determined using the incremental difference between Unified Cycle Phase[33] One (UC_{P1}) and Unified Cycle Phase Three (UC_{P3}) base emission rates (BERs). New data from the automotive manufacturers' In-Use Verification Program (IUVP) and the CARB's Vehicle Surveillance Program (VSP) were used to derive these odometer-dependent UC_{P1} and UC_{P3} ERs. In addition, warm starts emission data collected in the most recent VSP were used to derive new soak correction factor curves equations (SoF). These are used to determine warm starts ERs from cold starts ERs. These updates are described in more detail in the following sections.

4.3.1.2.2. HISTORICAL METHOD FOR COMPUTING COLD START EMISSIONS

Since EMFAC2000 cold start emissions have been computed using a modal, or second-by-second, emission trace-based method. Using this method, a tech group's odometer dependent cold StER were computed by multiplying an odometer independent Start Correction Factor

[33] Phase 1 – 3 are equivalent to Bag 1 – 3

(StCF) against an odometer dependent tech group specific UC_{P1} BER, ER = StCF*UC_{P1}[34]. The StCFs differed by pollutant, as well as by the catalyst and fuel-injection type of the vehicle.

CARB staff had derived the StCFs, used in this model, in the late 1990s from data collected in CARB programs. Emission traces, from 238 vehicles driven on UC_{P1}, were analyzed. The first 100 seconds of the UC_{P1} emissions were assumed to be starts emissions. The StCF were then calculated as CE100/UC_{P1}; where CE100 was the cumulative emissions over the first 100s of UC_{P1}, in grams per start; and UC_{P1} was the ER over the entire 300s of UC_{P1}, in grams per mile. Thus, the StCF had units of miles per start; and multiplying the StCFs against the tech group specific UC_{P1} ERs gave odometer dependent starts ERs, in grams per start. The StCFs used in EMFAC from EMFAC2000 through EMFAC2014 are shown in Table 4.3-31.

Table 4.3-31: StCF used in prior versions of EMFAC

Pollutant	Non- Catalyst	Oxidation Catalyst	Three-Way Catalyst	
			Carb/TBI	MPFI
HC	0.4565	0.6010	0.6472	0.7897
CO	0.4283	0.5838	0.6087	0.8168
NO_x	0.2235	0.2306	0.3448	0.4948

CARB/TBI: Carbureted/Throttle-Body Fuel Injection
MPFI: Multipoint Fuel Injection

4.3.1.2.3. ISSUES WITH THE HISTORICAL METHOD

Since the Historical Starts Method is now over 15 years old, and vehicular emissions have changed considerably since the 1990s, CARB staff investigated whether the method should still be used in EMFAC. Staff examined HC, NO_X, and CO emission traces from 11 recent model-year LEV2 SULEVs driven on the UC cycle, and computed their cold start emissions using the Historical Method.

Two major issues were identified. The first issue corresponded to the Historical Method's 100s starts cutoff point. For the higher NO_X emitting SULEVs, starts emissions persisted well beyond 100s; and in some cases, these late UC_{P1} emissions comprised the majority of emissions in the test phase (See Figures 4.3-36a and 4.3-36b). This indicated that EMFAC's Historical Method was undercounting starts emissions from higher NO_X emitting vehicles.

The second issue identified pertained to running exhaust emissions. In the Historical Starts Method it was assumed that all of the CE100 emissions are starts emissions, and that concurrent running exhaust emissions are negligible. EMFAC uses UC_{P2} to model running emissions and assumes that all of the emissions that occur in UC_{P2} are running emissions. In the sample of LEV2 SULEVs, examined by CARB staff, there were vehicles with UC_{P2} emissions greater than CE100 (See Figures 4.3-37a and 4.3-37b). This suggested that running exhaust emissions within CE100, might be non-negligible. Since EMFAC computes running emissions in a separate method, it is likely that the model is "double counting" the running exhaust emissions through starts emissions calculation methodology.

[34] EMFAC2000 Technical Documentation, Section 6.7 Start Correction factors

Figure 4.3-36a: Modal NO_X trace, from 2005 BMW325i showing late UC_{P1} emissions.

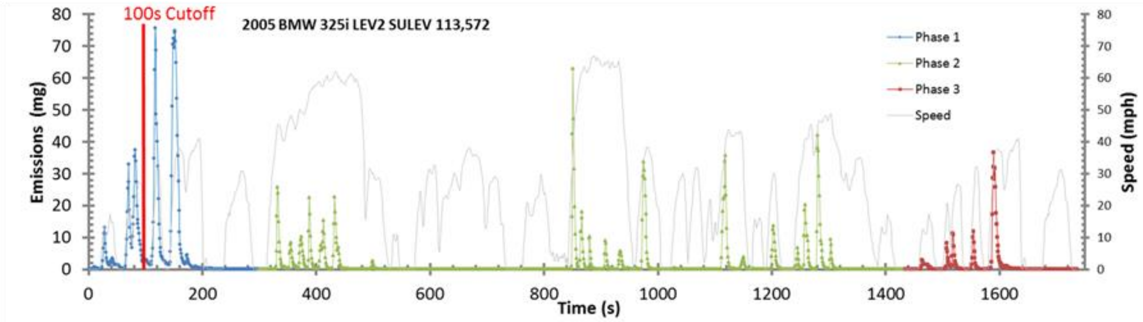


Figure 4.3-36b: Modal NO_X trace, from 2004 Nissan Altima showing late UC_{P1} emissions.

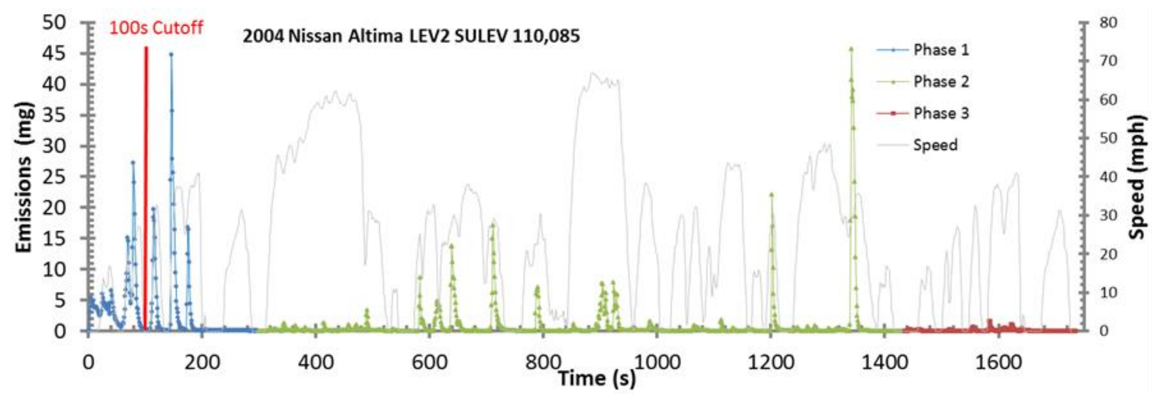


Figure 4.3-37a: Cumulative modal HC trace, from 2007 GM Ion showing substantial UC_{P2} emissions relative to CE100.

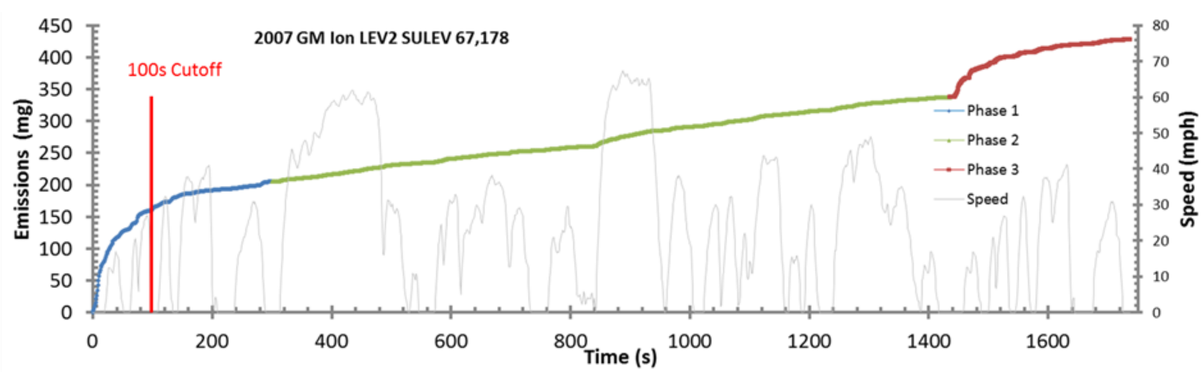
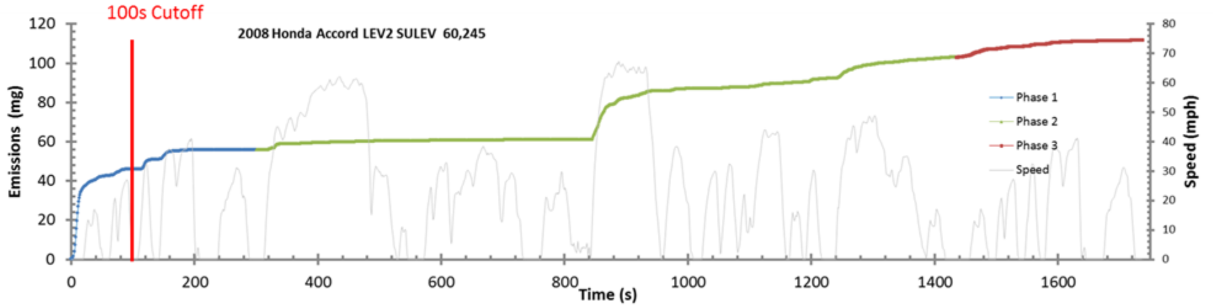


Figure 4.3-37b: Cumulative modal HC trace, from 2008 Honda Accord showing substantial UC_{P2} emissions relative to CE100.



One negative aspect, of the Historical Starts Method, is the requirement of modal data analysis to derive StCFs. Modal data analysis is time consuming and requires that the pollutant being measured has a reliable modal measurement method. Modal measurement methods have not yet been fully implemented for some pollutants, such as particulate matter.

4.3.1.2.4. INVESTIGATION OF ALTERNATIVE STARTS METHODS

Staff also explored several alternative methods to the Historical Method. Starts emissions were determined for the 11 LEV2 SULEVs using the alternative methods. Like the Historical Method, the methods examined were UC based and most required modal data analysis, involving a "subtracting out" of running exhaust emissions from starts emissions. They differed from each other on what portion of the UC emissions were considered starts emissions and what portion were considered running emissions.

A non-modal method or "Phase-Integrated Method" was also investigated. The method is similar to the method used by the U.S. EPA[35] to compute LDV starts emissions. The U.S. EPA's MOVES model derives cold start emissions by subtracting out all of the Federal Test Procedure-75 cycle's phase three emissions (FTP_{P3}), from the phase one (FTP_{P1}) emissions. Since the driving traces of FTP_{P1} and FTP_{P3} are identical, the emission difference is assumed to be due to the difference in the lengths of the soak periods that precede the phases. The FTP_{P1} begins with a cold start that follows a 12 hour or more soak of the vehicle. FTP_{P3}, on the other hand, begins with a hot start that follows a very short 10-minute soak of the vehicle, and thus starts emissions are assumed to be negligible. The main benefit of the "Phase-Integrated Method" is that it does not require modal data analysis.

CARB staff investigated the Phase-Integrated Method, using the UC cycle instead of the FTP cycle since the UC cycle is more representative of California driving patterns. Similar to the FTP, the driving traces of UC_{P1} and UC_{P3} are also equal. Like FTP_1 and FTP_3, UC_{P1} are preceded by 12+ hour and 10-minute soak periods respectively. It is acknowledged that UC_{P3} emissions may contain some starts emissions due to the 10-minute soak. However, preliminary

[35] USEPA 2014, Exhaust Emission Rates for Light-Duty On-road Vehicles in MOVES2014 Section 1.4.1.1.2 Defining Start Emissions

results from a CARB assessment indicate that the impact of these emissions on the computed cold start emissions is less than 10 percent.

The methods explored in the Alternative Starts Methods Investigation are summarized below.

CARB's Historical Method. Starts emissions (StE) are equal to the sum of the emissions over the first 100s of UC_{P1}; that is StE = $P1_{100}$

Phase-Integrated Method. Starts emissions are equal to the total emissions of UC_{P1} minus the total emissions of UC_{P3}; that is StE = P1-P3

Alternative Modal Method 1. Starts emissions are computed by taking the cumulative emissions, from the entire 300s of UC_{P1}, which consist of both starts and running emissions, and subtracting out the running emissions. The running emissions are estimated by taking the cumulative emissions from all 1135s of UC_{P2}, which are assumed to consist entirely of running emissions, and normalizing them to a 300s equivalent. This is accomplished by multiplying the cumulative running emissions by the ratio 300s/1135s; that is StE = P1 - 300/1135*P2

Alternative Modal Method 2. Similar to Alt Modal Method 1, starts emissions are computed by taking the cumulative emissions, from UC_{P1}, and subtracting out an estimate of the running emissions. In Alt Modal Method 2, the running emissions are calculated by first identifying a time (t_A) in the modal data trace of phase 1 where the emissions become nearly constant with time. Where the emissions become constant suggests they are mostly running emissions. The cumulative emissions between t_A and the end of Phase 1 (t_B) are then determined. Those emissions are then normalized to 300s by multiplying them by the ratio 300s/(t_A – t_B); that is StE = P1 – 300/(t_B-t_A)*(P1 – $P1_A$)

LEV2 SULEV starts results are shown in Table 4.3-32a for NO_X, Table 4.3-32b for HCs, and Table 4.3-32c for CO. Higher NO_X starts emissions were returned by the Phase-Integrated Method and the Alt Modal Methods 1 and 2, which counted all of the UC_{P1} emissions as starts emissions. The highest NO_X emitting vehicles, the 2004 Nissan Altima and the 2005 BMW 325i, tended to emit a very large percentage of their starts NO_X emissions in late $UC_{P1.}$

The computed HC and CO emissions were similar between the Historical Method and the alternative methods. Vehicles with noticeable deviations between method results included the 2004 Nissan Altima and the 2007 GM Ion. The Altima had HC emissions that were high in late-UC_{P1} which lead to larger computed starts emissions from the alternative methods. The 2007 GM Ion had higher than normal UC_{P3} emissions, which led to the Historical Method returning larger starts emission results than the other methodologies. The CO emissions of two vehicles, the 2004 BMW 325i and the 2008 Honda Accord were unusually high in UC_{P2}. Because modal Alt Method One employed UC_{P2} to correct for running emissions in UC_{P1}, this methodology returned negative starts emissions

Table 4.3-32a: NO_X Starts Emissions from LEV2 SULEVs using different starts methodologies.

NO_X	ARB Historical Method $P1_{100s}$ (mg)	Phase-Integrated Method P1 – P3 (mg)	Alt Modal Method 1 P1 – 300/1135*P2 (mg)	Alt Modal Method 2 $P1–[300/(t_B-t_A)]*P1_{B-A}$ (mg)
2004 Toyota Camry LE	218	213	201	215
2004 BMW 325i	115	100	106	100
2007 VW Jetta	53	61	59	48
2009 Toyota Camry	195	199	191	190
2004 Nissan Altima	449	892	656	880
2007 GM Ion	41	37	33	39
2007 Hyundai Elantra	123	125	118	121
2011 Toyota Camry	75	76	71	73
2005 BMW 325i	605	1578	1508	1976
2004 Ford Focus	77	74	70	75
2008 Honda Accord	97	93	80	94
Mean	188 mg	316 mg	281 mg	346 mg

Table 4.3-32b: HC Starts Emissions from LEV2 SULEVs using different starts methodologies.

HC	ARB Historical Method $P1_{100s}$ (mg)	Phase-Integrated Method $P1_{300s} – P3_{300s}$ (mg)	Alt Modal Method 1 $P1_{300}$ – 300/1135*$P2_{1135}$ (mg)	Alt Modal Method 2 $P1_{300} – [300/(t_B-t_A)]*P1_{B-A}$ (mg)
2004 Toyota Camry LE	153	156	161	158
2004 BMW 325i	234	233	240	238
2007 Volkswagen Jetta	48	47	53	37
2009 Toyota Camry	204	207	206	208
2004 Nissan Altima	178	262	287	285
2007 GM Ion	161	114	170	151
2007 Hyundai Elantra	97	95	98	97
2011 Toyota Camry	98	97	107	102
2005 BMW 325i	146	142	132	147
2004 Ford Focus	85	76	76	81
2008 Honda Accord	46	47	43	55
Mean	132 mg	134 mg	143 mg	142 mg

Table 4.3-32c: CO Starts Emissions from LEV2 SULEVs using different starts methodologies.

CO	ARB Historical Method $P1_{100s}$ (mg)	Phase-Integrated Method $P1_{300s} – P3_{300s}$ (mg)	Alt Modal Method 1 $P1_{300}$ – $300/1135*P2_{1135}$ (mg)	Alt Modal Method 2 $P1_{300} – [300/(t_B-t_A)]*P1_{B-A}$ (mg)
2004 Toyota Camry LE	1894	1887	1867	1826
2004 BMW 325i	1715	1617	-738	1765
2007 Volkswagen Jetta	1898	1919	480	1852
2009 Toyota Camry	1825	1809	1794	1812
2004 Nissan Altima	5148	4705	6519	6220
2007 GM Ion	3585	4186	3631	3099
2007 Hyundai Elantra	1982	2396	2628	1977
2011 Toyota Camry	1074	1218	936	1287
2005 BMW 325i	1304	1285	1284	1195
2004 Ford Focus	1251	1294	629	1184
2008 Honda Accord	389	507	-114	136
Mean	2006 mg	2075 mg	1720 mg	2032 mg

Based upon the results of the investigation into alternative starts methods, and the inherent advantages of a non-modal approach to starts, CARB Staff made the decision to implement the Phase-Integrated Starts Method in EMFAC2017.

4.3.1.2.5. PHASE-INTEGRATED METHOD RESULTS

EMFAC2017's Phase-Integrated Starts Method StER computes cold start emissions as follows:

$$StER = 1.2\ mi*(UC_{P1}\ BER - UC_{P3}\ BER) \qquad \text{(Eq. 4.3-4)}$$

In this equation, UC_{P1} BER and UC_{P3} BER are the pollutant, EMFAC Technology Group, and odometer dependent base emission rates of the Unified Cycle's Phase 1 and 3; and 1.2 mi is the driving distance of these phases. Thus, the cold StER also depends upon pollutant, EMFAC Technology Group, and odometer. The odometer dependence allows EMFAC2017 to account for the effects of emission deterioration within the fleet. Please refer to last section of Chapter One for information on these BERs including their equations, information on how they were derived, and a discussion on how they change with odometer and differ across emission technology groups.

Figure 4.3-38a displays EMFAC2017's and EMFAC2014's odometer dependent HC cold StERs for vehicles belonging to LEV1 emission groups. Both model versions predict lower emissions for the LEV1 ULEV emission group vehicles, which have more stringent NMOG standards. LEV1 ULEVs certify to 40 mg/mi through 50kmi and 55 mg/mi through 100kmi; while the analogous LEV1 LEVs limits are 75 mg/mi and 90 mg/mi. For both ULEVs and LEVs, EMFAC2017's HC cold StERs are approximately double those of EMFAC2014 for mileages under 100kmi.

EMFAC2017 and EMFAC2014 HC cold StERs for LEV2 LEV, LEV2 ULEV, and LEV2 SULEV vehicles are shown in Figure 4.3-38b. The EMFAC2017 HC emission rates are much greater than their EMFAC2014 counterparts, especially at low mileages. For instance, the EMFAC2017

HC cold StER is almost an order of magnitude greater for LEV2 SULEVs. SULEVs have an EMFAC2014 HC cold StER of 13 mg/mi versus an EMFAC2017 cold StER of almost 105 mg/mi. For both versions of the model, the cold StERs correlate with the 120 kmi NMOG regulatory limits, which are 90 mg/mi for LEV2 LEVs, 55 for LEV2 ULEVs mg/mi, and 10 mg/mi for LEV2 SULEVs.

Figures 4.3-38c and 4.3-38d illustrate LEV1 and LEV2 cold StERs as a function of mileage for NO_X. Notice that EMFAC2014 assumed identical NO_X cold StERs for LEV1 LEV and LEV1 ULEV vehicles. This is because EMFAC2014 emission rates were derived using a ratio of standards approach and these groups had identical NO_X standards. Conversely, EMFAC2017 uses a larger NO_X cold StER for LEV1 LEVs. EMFAC2017's cold start ERs were based upon real-data from the IUVP and VSP programs. These data indicated that LEV1 LEV vehicles emit NO_X at a substantially higher rate than LEV1 ULEVs. The IUVP/VSP data also showed that deterioration was much less substantial than assumed in EMFAC2014, and that is reflected in curves in Figure 4.3-38c.

The IUVP/VSP data analysis returned LEV2 LEV and LEV2 ULEV cold StERs that were nearly identical across all relevant mileages. This is likely a result of the fact that vehicles belonging to these emission groups were calibrated to meet identical NO_X emission standards of 50 mg/mi at 50 kmi, and 70 mg/mi at 120kmi. In general, the EMFAC2017 LEV2 NO_X cold StERs are greater than their EMFAC2014 counterparts. This may be partially due to the method change. The Investigation of Alternative Start Methodologies, described earlier, showed that the Phase-Integrated Method returns NO_X cold StERs that are approximately double those of the Historical Method. Deterioration was non-existent in LEV2 LEVs and ULEVs, but quite substantial for LEV2 SULEVs, which had substantial moderate and high regime fractions at higher mileages.

Figure 4.3-38a: EMFAC2017 and EMFAC2014 HC Cold StERs for LEV1 Emission Groups

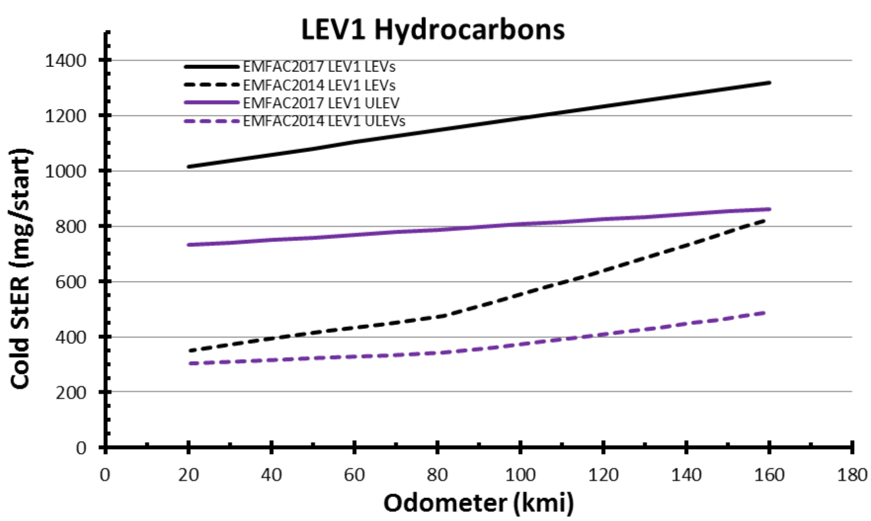


Figure 4.3-38b: EMFAC2017 and EMFAC2014 HC Cold StERs for LEV2 Emission Groups

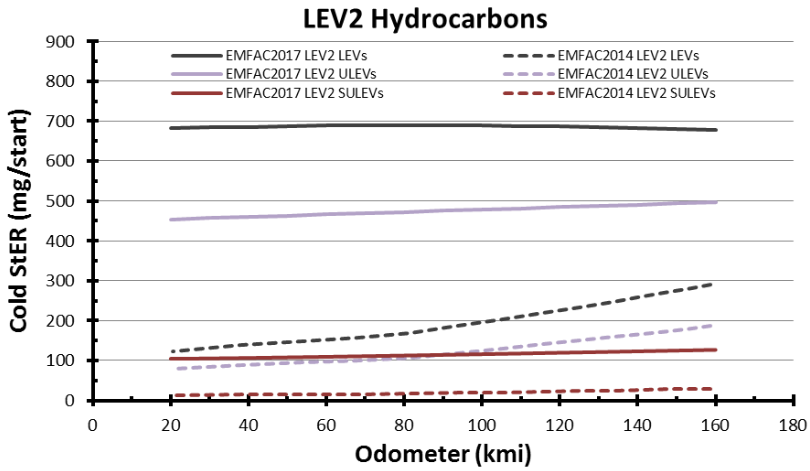


Figure 4.3-38c: EMFAC2017 and EMFAC2014 NOx Cold StERs for LEV1 Emission Groups

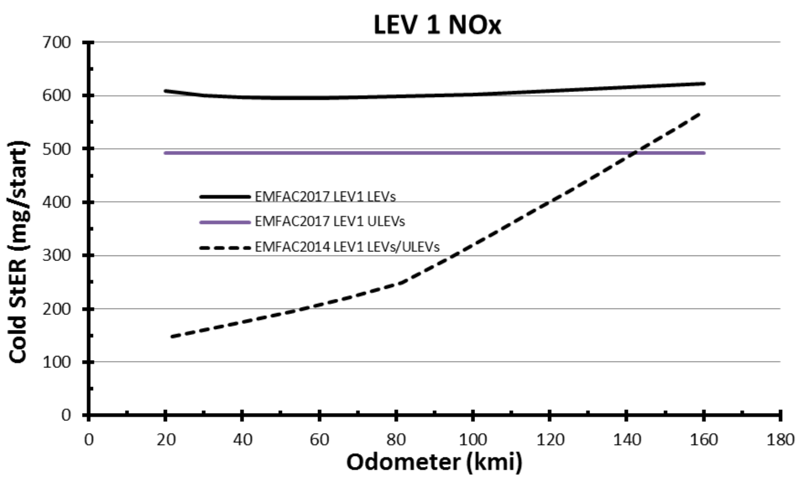
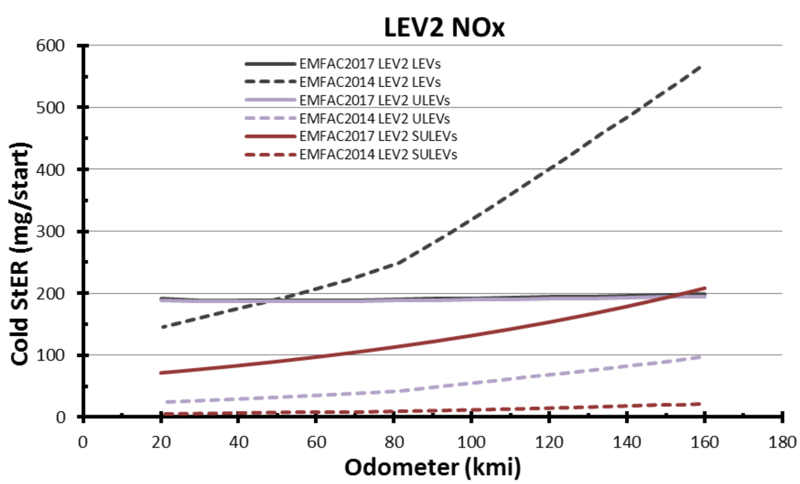


Figure 4.3-38d: EMFAC2017 and EMFAC2014 NOx Cold StERs for LEV2 Emission Groups



4.3.1.2.6. EMFAC2017 WARM STARTS UPDATE

The results of a recent statewide survey of the driving behaviors of California residents, the California Household Travel Survey 2010 – 2012, showed that warm starts now constitute the majority, 88.1 percent of all LDV starts (*CHTS 2010 – 2012*[36]). Depending upon the pollutant and the length of soak, a vehicle's warm StER can be similar, in magnitude, to its cold StER. Therefore, for an accurate LDV inventory, it's important to accurately compute warm starts emissions. EMFAC currently assumes that a vehicle's warm StER are directly proportional to its odometer equivalent cold StER. A warm StERs is computed by multiplying the cold StER by a non-dimensional soak correction factor (SoF), which is a function of soak time t.

Warm StER(odo)= Cold StER(odo)*SoF(t) (Eq. 4.3-5)

Data from the most recent CARB's VSP indicate that the assumption of proportionality between cold and warm start StERs is still valid for newer vehicles; and this aspect of the starts methodology will remain in place in EMFAC2017. However, for EMFAC2017, staff have incorporated new SoF equations that are based upon testing of the most recent vehicle model years and technologies. These tests assessed how starts emissions changed as a function of soak time, for soak times less than the 12 hour cold start cut-off.

4.3.1.2.7. HISTORY OF THE SOAK CORRECTION FACTOR EQUATIONS

EMFAC2014's SoF curve equations were developed in the late-1990s. At that time, CARB staff used warm and cold start emission data from over 200 vehicles to derive SoF equations. These equations transformed cold StERs to warm StERs via equation 4.3-5. Different equations were used for different pollutants and vehicle catalyst technologies (three-way catalyst, oxidation catalyst, or no catalyst). SoFs were assigned to the various tech groups of EMFAC based upon the catalyst technologies of the vehicles in those tech groups.

Today the vast majority of LDVs use three-way catalyst technologies. Thus, for EMFAC2017, staff decided to develop emission group specific SoFs. This choice was based on the assumption that vehicles belonging to the same emission group have similar emission behavior as a function of soak time.

4.3.1.2.8. DERIVATION OF NEW SOAK CORRECTION FACTOR CURVE

Warm starts emission data from 85 LEV1 and LEV 2 certified vehicles tested as part of the most recent VSP were used to derive new SoF curves for HC (NMOG), NO_X, and CO. The vehicles were driven UC_{P1}, following several different periods of soak. The soak periods varied from 50 min to 720 min (12 hr soak time).

Per the new starts methodology, the phase-integrated UC_{P1} emissions measured during these warm starts tests were corrected for running exhaust emissions. This was done by subtracting

---

[36] California Household Travel Survey 2013 http://www.dot.ca.gov/hq/tpp/offices/omsp/statewide_travel_analysis/files/CHTS_Final_Report_June_2013.pdf

out the emission results of the 10 min soak warm starts test, which was equivalent to a UC_{P3} test. The UC_{P1} – UC_{P3} differences were plotted versus the soak time of the UC_{P1} test. Regression curves were then fitted to the data to derive un-normalized soak correction factor curves.

Quadratic and linear functions were used because they provided the best fits to the data (although log, exponential and power curves were examined in each fit). Similar to prior versions of EMFAC, a two domain approach was used. For the curve fitting, the plots were divided into short soak warm starts and long soak warm starts and separate curves were fitted to each domain. The curves were forced through the y-intercept based on the assumption that starts emissions are zero for zero-minute soak tests. The curves were then normalized by dividing their coefficients by the values of the high domain curve at 720 min. This was to ensure that the high domain SoF curves had a value SoF(t = 720 min) = 1.

4.3.1.2.9. EQUATIONS SOAK CORRECTION FACTOR CURVE RESULTS

The results for vehicle specific HC warm StERs, 1.2*(UC_{P1} – UC_{P3}) as a function of UC_{P1} soak time are plotted in Figures 4.3.39a through 4.3-43a below. Data are organized by emission group. These data were used to derive the new SoF curves shown in Figures 4.3.39b through 45b. Figures 4.3-39b through 4.3-43b also illustrate the curves employed for the same emission groups in EMFAC2014. Note that EMFAC2014 used the same SoF curves for all LEV1 and LEV2 emission groups.

For all three pollutants examined, a domain cutoff between 40 – 90 min lead to the best regression fits for all three pollutants. The exact cutoff point used in EMFAC2017 was determined by where the high and low domain SoF equations intersect, giving a smooth response of emissions as function of soak time.

Figure 4.3-39a: HC Starts Emission Rates, as a Function of Soak Time, for CARB Tested LEV1 LEV Vehicles.

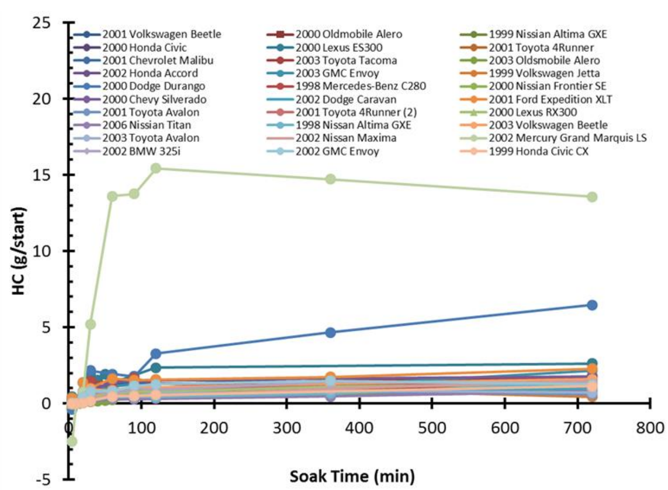


Figure 4.3-39b: EMFAC2017 and EMFAC2014 LEV1 LEV HC Soak Correction Factor Curves

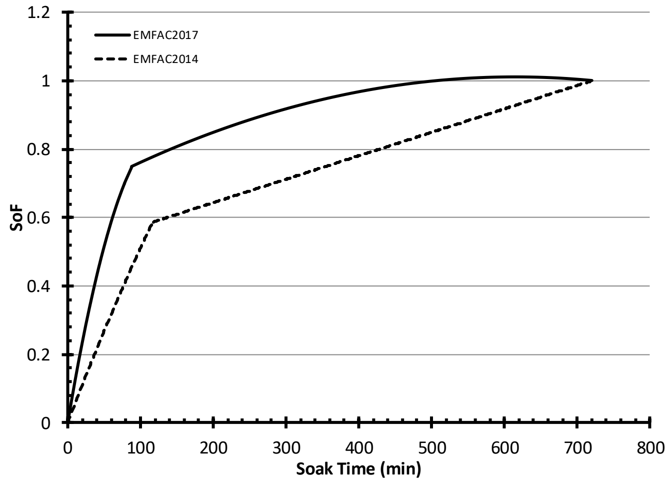


Figure 4.3-40a: HC Starts Emission Rates, as a Function of Soak Time, for CARB Tested LEV1 ULEV Vehicles

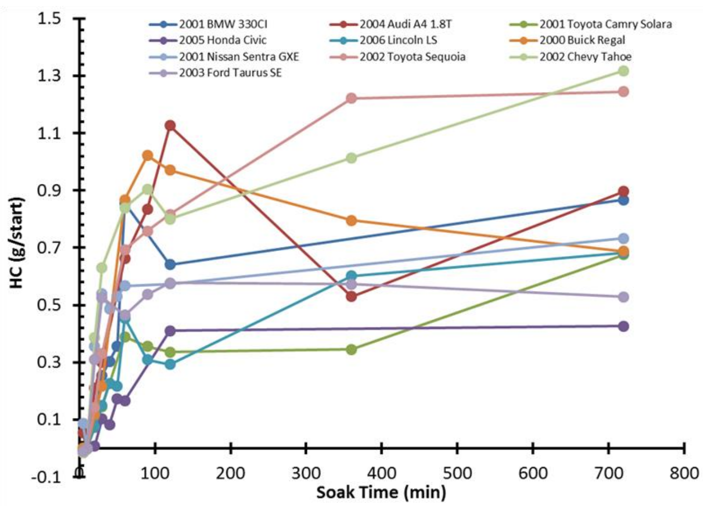


Figure 4.3-40b: EMFAC2017 and EMFAC2014 LEV1 ULEV HC Soak Correction Factor Curves

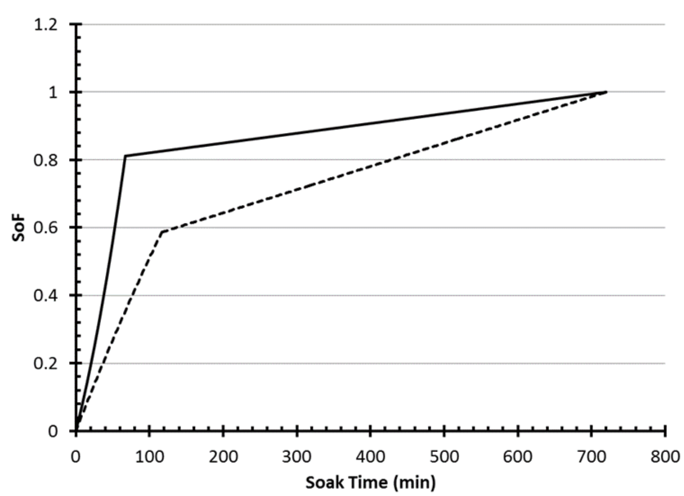


Figure 4.3-41a: HC Starts Emission Rates, as a Function of Soak Time, for CARB Tested LEV2 LEV Vehicles

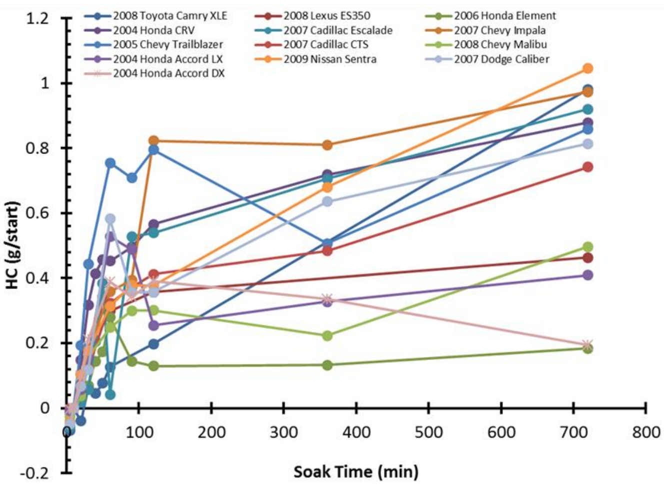


Figure 4.3-41b: EMFAC2017 and EMFAC2014 LEV2 LEV HC Soak Correction Factor Curves

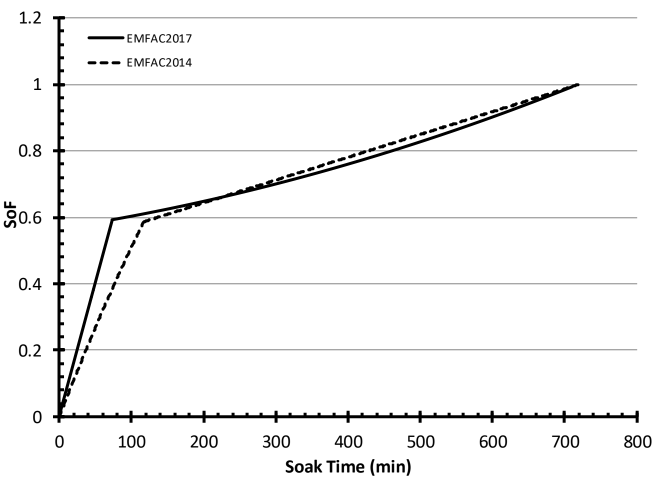


Figure 4.3-42a: HC Starts Emission Rates, as a Function of Soak Time, for CARB Tested LEV ULEV Vehicles

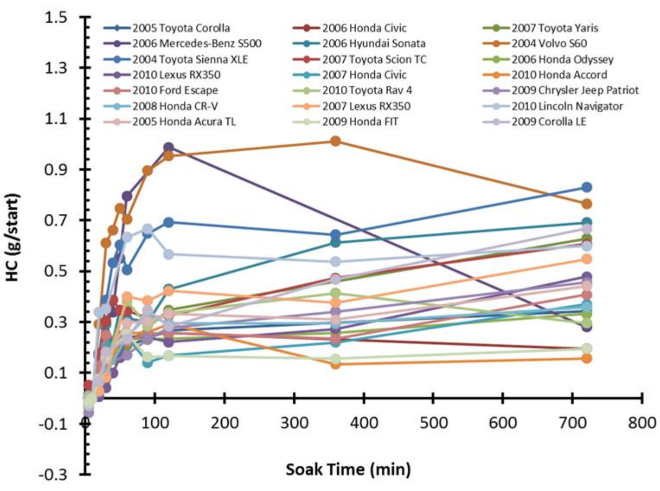


Figure 4.3-42b: EMFAC2017 and EMFAC2014 LEV2 ULEV HC Soak Correction Factor Curves

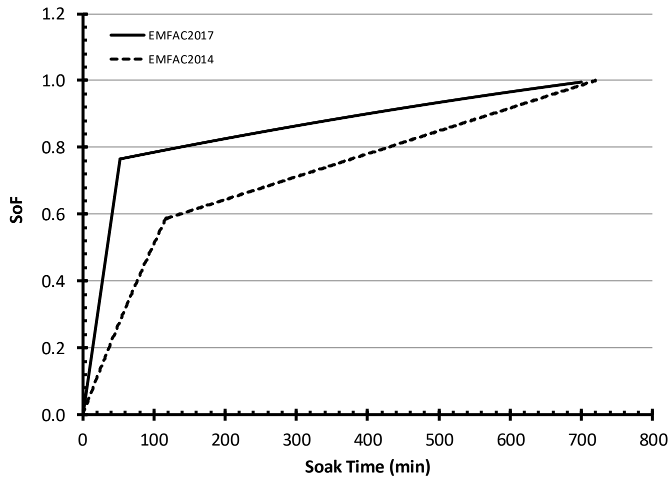


Figure 4.3-43a: HC Starts Emission Rates, as a Function of Soak Time, for CARB Tested LEV2 SULEV Vehicles

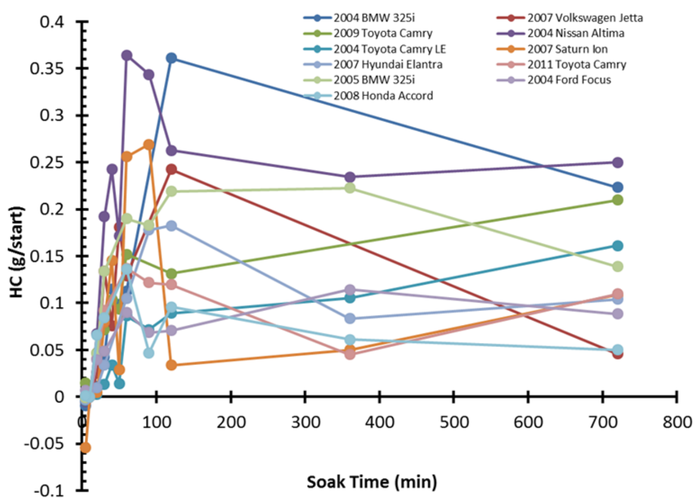
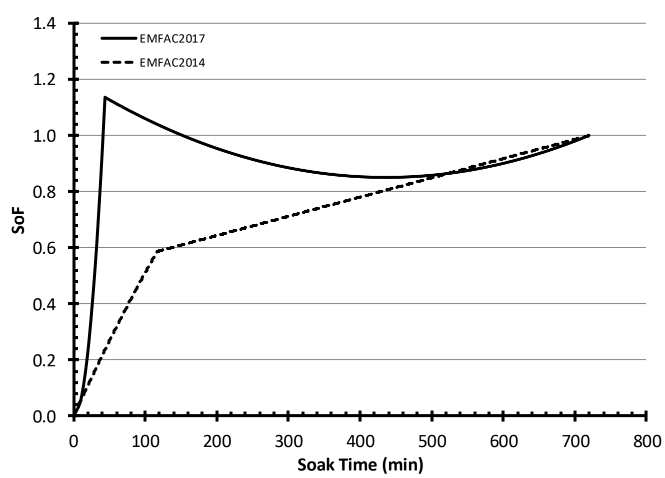


Figure 4.3-43b: EMFAC2017 and EMFAC2014 LEV2 SULEV HC Soak Correction Factor Curves



For HC, the EMFAC2017 SoF curves return higher emission rates for tests that follow moderate-length soak periods, for all LEV1 and LEV2 emission groups. The difference is most pronounced in LEV2 SULEVs (Figure 4.3-43b), where the EMFAC2017 SoF (t = 60 min) is approximately triple the EMFAC2014 SoF (t = 60 min). For LEV2 SULEVs, HC emissions in warm starts following 60 – 120 min of soak, are actually higher than cold start emissions, as indicated by SoF(t) > 1.

NO_X StERs are plotted in Figures 4.3-44a to 4.3-48a and the new SoF curves are shown in Figures 4.3-44b to 4.3-48b. For NO_X, starts emissions tended much more strongly influenced by soak time than the relatively flat response given by the EMFAC2014 LEV1/LEV2 NO_X SoF. Warm starts emissions, for tests that follow moderate length soak periods in the range of 60-120 min tended to be greater than cold start emissions; hot starts emissions, following short soaks of less than 20-30 min tended to be much lower. The sensitivity of NO_X starts emissions to soak time was most pronounced in the LEV2 emission groups. In LEV2 ULEVs and LEV2 SULEVs NO_X warm starts emissions exceeded cold start emissions by a factor of 2.5 at moderate length soaks.

For CO, the response of warm starts emissions, as a function of soak time tend to be similar to HC. SoF curve types, parameters, and domain cutoffs for CO and the other pollutants are shown in Table 4.3-33. The computed soak curves were mapped to the relevant EMFAC Tech Groups as shown in Table 4.3-34.

Figure 4.3-44a: NO_X Starts Emission Rates, as a Function of Soak Time, for CARB Tested LEV1 LEV Vehicles

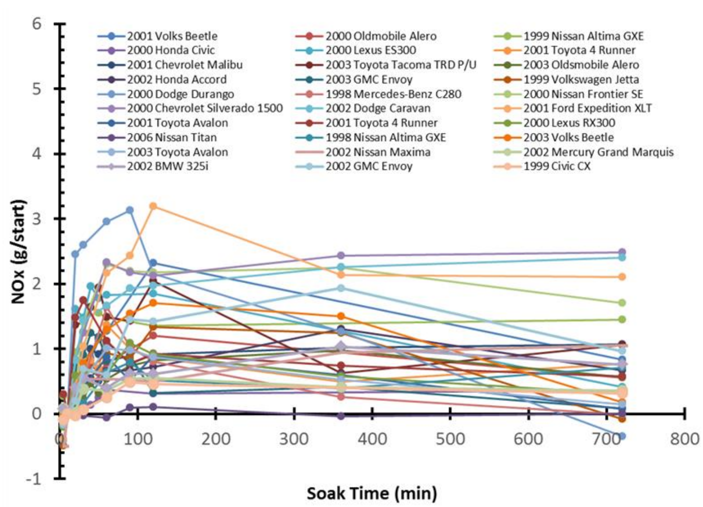


Figure 4.3-44b: EMFAC2017 and EMFAC2014 LEV1 LEV NOx Soak Correction Factor Curves

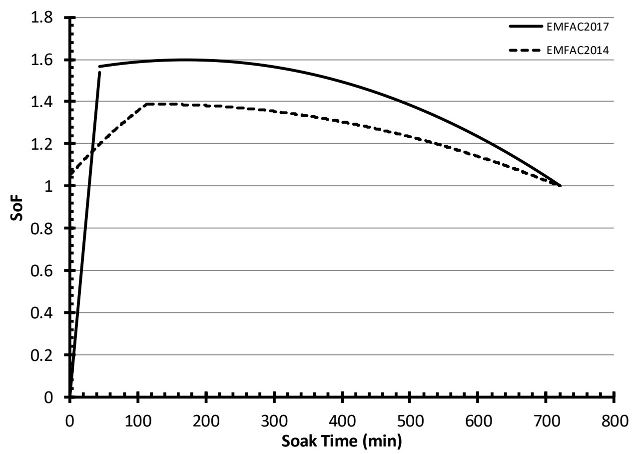


Figure 4.3-45a: NO_X Starts Emission Rates, as a Function of Soak Time, for CARB Tested LEV1 ULEV Vehicles

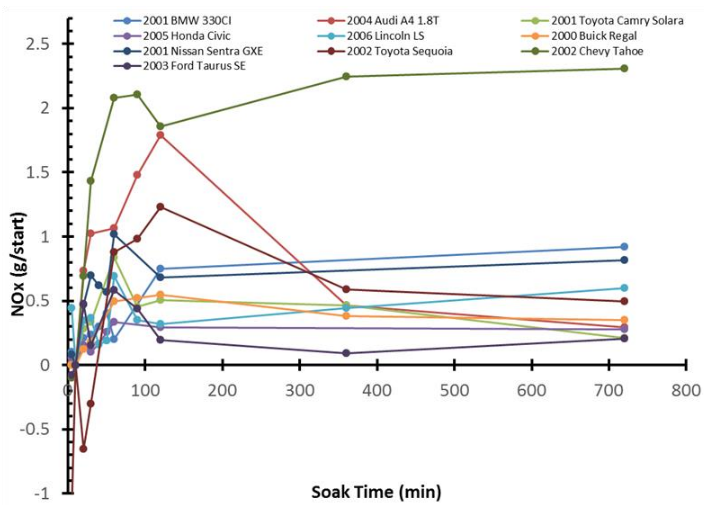


Figure 4.3-45b: EMFAC2017 and EMFAC2014 LEV1 ULEV NOx Soak Correction Factor Curves

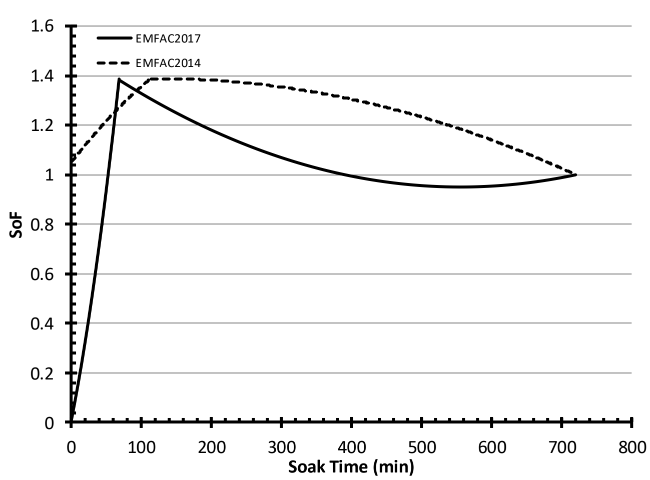


Figure 4.3-46a: NOx Starts Emission Rates, as a Function of Soak Time, for CARB Tested LEV2 LEV Vehicles

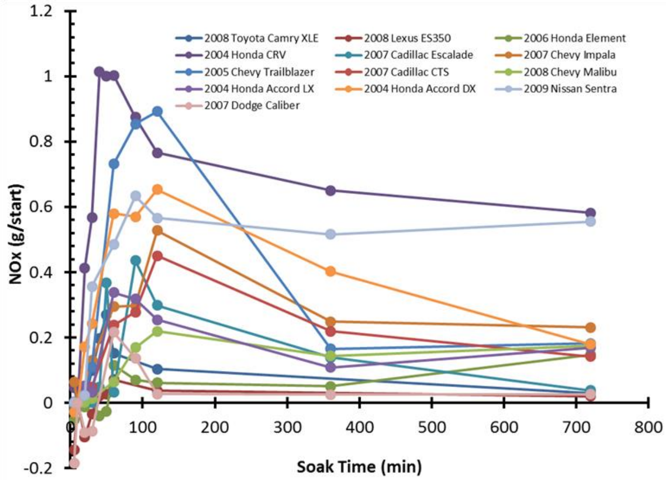


Figure 4.3-46b: EMFAC2017 and EMFAC2014 LEV2 LEV NOx Soak Correction Factor Curves

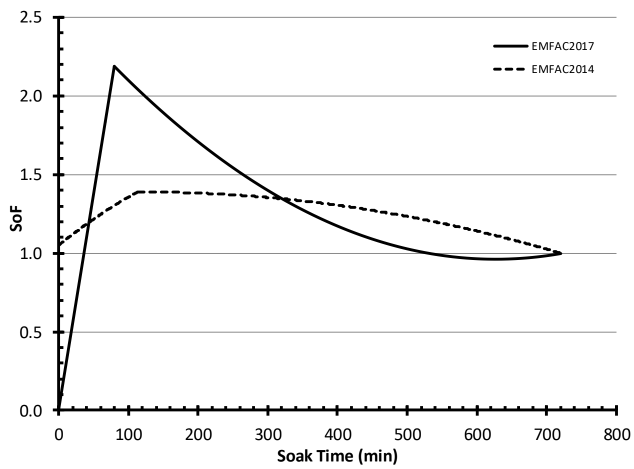


Figure 4.3-47a: NOx Starts Emission Rates, as a Function of Soak Time, for CARB Tested LEV2 ULEV Vehicles

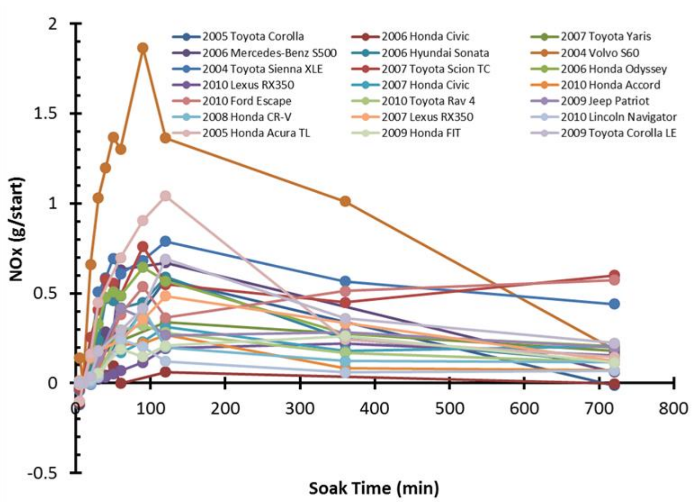


Figure 4.3-47b: EMFAC2017 and EMFAC2014 LEV2 ULEV NOx Soak Correction Factor Curves

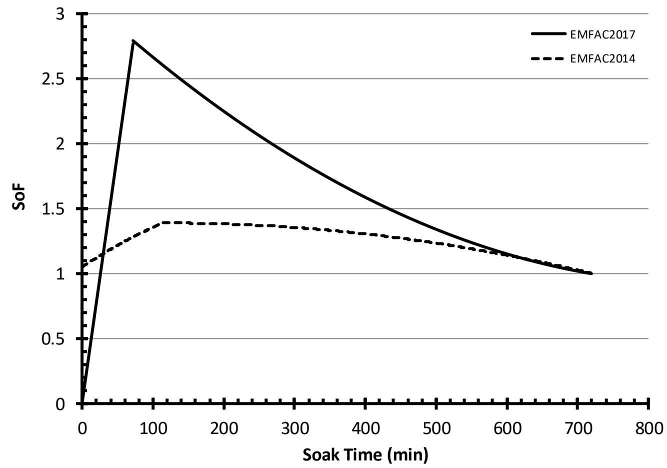


Figure 4.3-48a: NOx Starts Emission Rates, as a Function of Soak Time, for CARB Tested LEV2 SULEV Vehicles

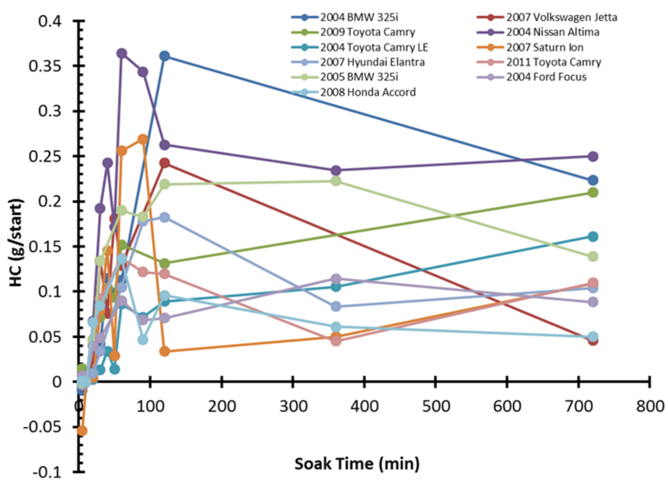


Figure 4.3-48b: EMFAC2017 and EMFAC2014 LEV2 SULEV NOx Soak Correction Factor Curves

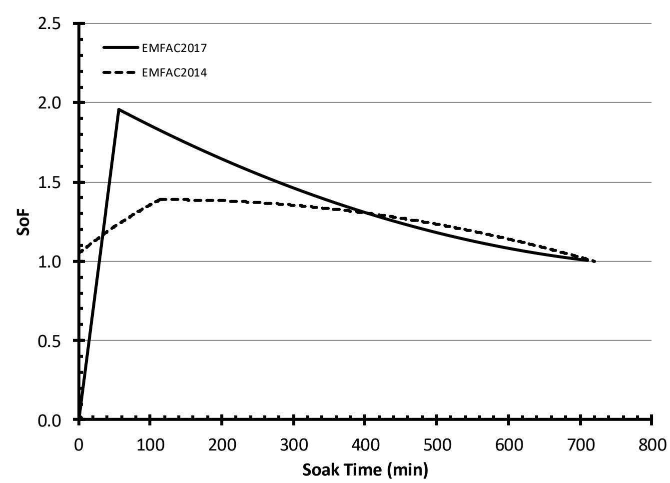


Table 4.3-33: HC, NO_X, and CO Soak Correction Factor Curve Equation Parameters LEV1 and LEV2 Emission Groups

Emission Group	Pollutant	SoF Equation for Domain 1					SoF Equation for Domain 2				
		Equation Type	Domain (min)	a2	a1	a0	Equation Type	Domain (min)	a2	a1	a0
LEV1 LEV	HCs	Quadratic	0-88.3	-4.68E-05	0.0126	0	Quadratic	88.3-720	-9.47E-07	1.16E-03	0.653
LEV1 LEV	NO_X	Linear	0-44.2	/	0.0347	0	Quadratic	44.2-720	-1.98E-06	6.74E-04	1.54
LEV1 LEV	CO	Quadratic	0-78.5	-6.10E-05	9.16E-03	0	Quadratic	78.5-720	-1.88E-06	2.52E-03	0.158
LEV1 ULEV	HCs	Quadratic	0-67.2	5.25E-05	8.56E-03	0	Quadratic	67.2-720	1.84E-09	2.88E-04	0.792
LEV1 ULEV	NO_X	Quadratic	0-68.9	8.37E-05	0.0143	0	Quadratic	68.9-720	1.83E-06	-2.03E-03	1.52
LEV1 ULEV	CO	Linear	0-46.9	/	0.0118	0	Linear	46.9-720	/	6.64E-04	0.522
LEV2 LEV	HC	Linear	0-72.4	/	0.008153	0	Quadratic	72.4-720	3.73E-07	3.36E-04	5.65E-01
LEV2 LEV	NO_X	Linear	0-80.1	/	2.73E-02	0	Quadratic	80.1 -720	4.11E-06	-5.14E-03	2.58
LEV2 LEV	CO	Quadratic	0-58.4	3.93E-05	4.84E-03	0	Linear	58.4-720	/	8.80E-04	0.3665
LEV2 ULEV	HC	Linear	0-51.9	/	1.47E-02	0	Quadratic	51.9-720	-1.13E-07	4.39E-04	0.742
LEV2 ULEV	NO_X	Linear	0-72.7	/	0.0383	0	Quadratic	72.7-720	2.83E-06	-5.00E-03	3.14
LEV2 ULEV	CO	Linear	0-67.9	/	9.38E-03	0	Quadratic	67.9-720	-1.13E-07	6.46E-04	0.594
LEV2 SULEV	HC	Quadratic	0-43.8	5.91E-04	7.06E-05	0	Quadratic	43.8-720	1.86E-06	-1.62E-03	1.2
LEV2 SULEV	NO_X	Linear	0-55.7	/	3.51E-02	0	Quadratic	55.7-720	1.40E-06	-2.53E-03	2.09
LEV2 SULEV	CO	Quadratic	0-74.1	-2.13E-06	1.56E-02	0	Quadratic	74.1-720	-1.16E-06	7.05E-04	1.1

Table 4.3-34: Mapping of Computed Soak Curves to EMFAC2017's Tech Groups

Soak Correction Factor Curve	EMFAC Technology Group
LEV1 LEV	19-23, 26, 27
LEV1 ULEV	24
LEV2 LEV	28, 34, 36
LEV2 ULEV	29, 39, 44
LEV2 SULEV	30, 31, 37, 38

4.3.1.3. LD CO2 SPEED CORRECTION FACTORS

The CO_2 Speed Correction Factors (SCFs) used for light-duty vehicles in EMFAC2014 were based on a set of 12 dynamometer driving cycles referred to as the Unified Correction Cycles (UCC's). These 12 cycles were designed to be representative of an average trip at a given speed, where the mean speeds ranged from approximately 2.4 mph to 59.1 mph at 5 mph increments. The vehicles used in that analysis were selected from Light-Duty Surveillance Projects 2S95C1 and 2S97C1, conducted in 1995 and 1997 respectively, and from the research projects 2R9513 and 2R9811, which were conducted in 1995 and 1998.

The recent CARB's light-duty vehicle surveillance program started in calendar year 2011, LDVSP19 (Project 2S11C1) established the use of new dynamometer driving cycles to collect emissions data. Four arterial driving cycles and seven freeway cycles were developed and tested for use in LDVSP19. The average speed of each test cycle is shown below in Table 4.3-35.

Table 4.3-35: Arterial and Freeway Driving Cycles

Test Cycle		Average Speed (mph)
Arterial Cycle	MAC1	7
	MAC2	23
	MAC3	39
	MAC4	55
Freeway Cycle	MFC1	15
	MFC2	25
	MFC3	33
	MFC4	46
	MFC5	57
	MFC6	65
	MFC7	73

In Figure 4.3-49, the analysis of 95 vehicles tested in LDVSP19 show the following results for CO_2 emissions (grams per mile) by the average vehicle speed corresponding to the arterial and freeway driving cycles. A best fit equation was calculated through the raw data and was determined as a 3rd order polynomial as indicated below:

$$CO_2\ (g/mi) = -0.0047 \times Speed^3 + 0.7839 \times Speed^2 - 40.884 \times Speed + 980.43 \qquad (Eq.\ 4.3\text{-}6)$$

Using the above equation, the emissions were calculated and are shown in Table 4.3-36 below by speed bin for bins between 5 through 70 miles per hour. The speed bins were limited to 70 miles per hour in order to not exceed the average speed of the MFC7 Freeway Cycle.

The emissions were normalized to the speed of 27.4 miles per hour (CO_2 emissions of 352 grams per mile) and their results are shown as the EMFAC2017 CO_2 speed correction factors (SCFs) in Table 4.3-36 and plotted in Figure 4.3.50 by speed bin. The normalized CO_2 SCF data from EMFAC2014 and EMFAC17 SCF data are also plotted in Figure 4.3-50 for comparison.

Table 4.3-36: EMFAC17 CO_2 SCFs by Speed Bin

Speed Bin	CO_2 gm/mi	CO_2 SCF
5	795.020	2.258
10	645.280	1.833
15	527.685	1.499
20	438.710	1.246
25	374.830	1.065
30	332.520	0.945
35	308.255	0.876
40	298.510	0.848
45	299.760	0.851
50	308.480	0.876
55	321.145	0.912
60	334.230	0.949
65	344.210	0.978
70	347.560	0.987

Figure 4.3-49: CO_2 Emissions by Vehicle Speed

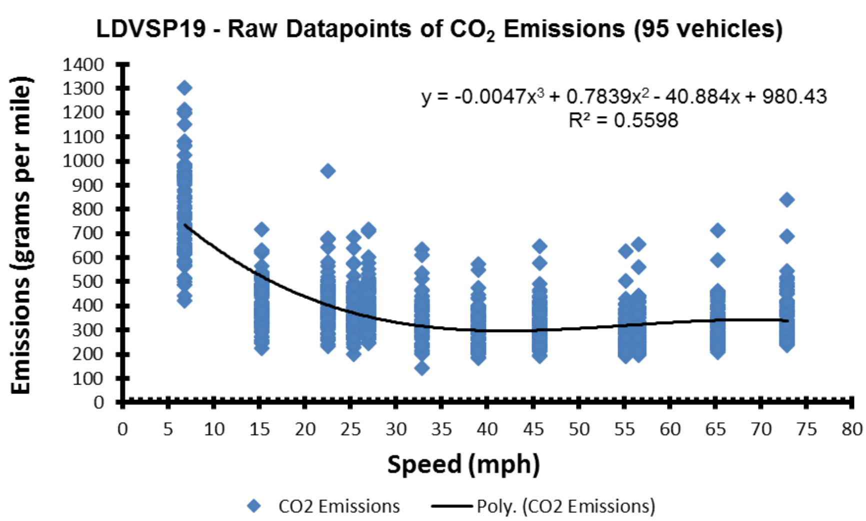
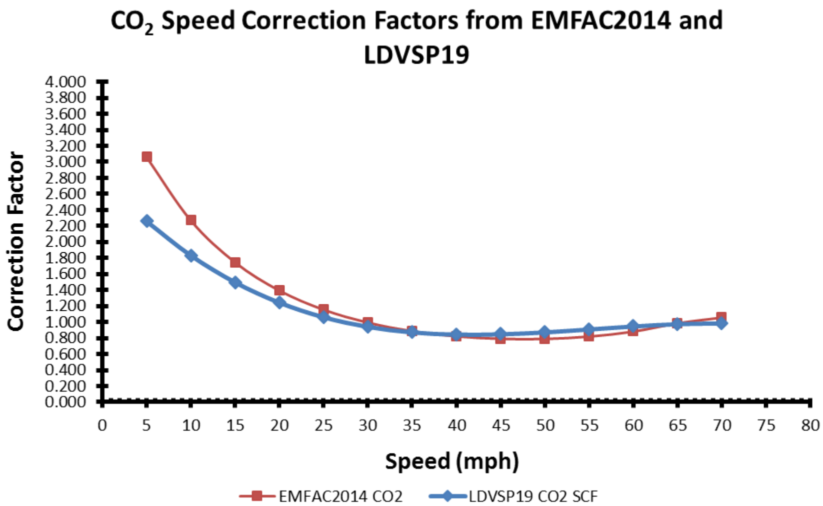


Figure 4.3-50: CO_2 Speed Correction Factors by Vehicle Speed Bin



For CO_2, these updated EMFAC2017 SCFs would be applied to all gasoline MPFI technology groups and for the vehicle classes of passenger vehicles through medium duty trucks.

4.3.1.4. MEXICAN VEHICLES

The emissions contribution of Mexican-plated vehicles operating in San Diego and Imperial counties was last updated in EMFAC2001[37]. In all likelihood, the activity and emissions behavior of these vehicles has changed dramatically. Staff has conducted a preliminary analysis of available Mexican plated vehicle emissions and believes that the current methodology substantially overestimates the impact of Mexican plated vehicles in the border areas. For EMFAC2017, CARB will treat Mexican plated vehicles the same as California plated vehicles until better information is made available. Activity issues, emissions issues, and future plans to improve these estimates are discussed below.

Approximately 2.6 million passenger vehicles enter California from Mexico every month[38]. Roughly half of these vehicles are Mexican plated[39]. The actual VMT from these vehicles is already implicit in the SANDAG VMT estimates[40]. However, the Mexican plated vehicles may have a significantly different distribution with respect to age and technology. During the EMFAC2001, it was found that the Mexican plated fleet was significantly older than California certified vehicles. The assumption that Mexican plated vehicles were older was carried into the future calendar years.

---

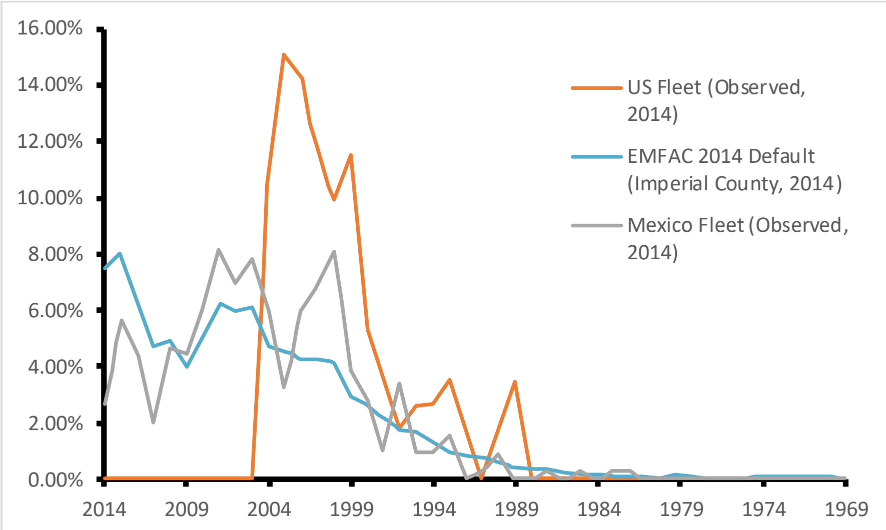
[37] https://www.arb.ca.gov/msei/emfac2001_docs.htm

[38] Bureau of Transportation Statistics

[39] Kear, Tom "Vehicle Idling Emissions Study at Calexico East and Calexico West Ports-of-Entry", September 2015

[40] http://www.sdforward.com/pdfs/RP_final/AppendixT-SANDAGTravelDemandModelDocumentation.pdf

Figure 4.3-51: Calexico Mexican Vehicle Activity



At least for the port of Calexico, staff has confirmed that the Mexican plated fleet age distribution is similar to that of EMFAC2014, and that the original age distribution difference is no longer valid. Until data can be gathered for other ports, staff will assume that the age distribution is equivalent to that of Imperial and San Diego counties. Also, approximately 85 percent of the vehicles operating at the Mexican border are former US vehicles[41]. Therefore, the technology group distributions are assumed to be the same as Californian vehicles for a given age.

Even if the age distribution and technology distribution are similar for the Mexican and California fleets, that does not necessarily mean the emission rates are similar. In the survey used for EMFAC2001, 40 to 50 percent of all of the Mexican vehicles were found to be tampered or otherwise mal-maintained. Similarly, 40 to 50 percent of those surveyed conceded that they had on occasion used leaded fuel, possibly poisoning the catalytic converter. Without updated data, CARB continued to use the emission factors from EMFAC2001 which resulted in an extrapolation of the Mexican plated vehicles being two orders of magnitude higher in emissions even for modern technology vehicles. This seems very unlikely given that these are former US vehicles and Baja has instituted a smog check program. The smog check program is reported to be struggling with tampering and other issues with respect to implementation, but it is unlikely these shortcomings would result in an increase in emissions of two orders of magnitude. Similarly, PEMEX has made improvements in the fuel quality. So for EMFAC2017, CARB staff believes it is more appropriate to use the same emission factors for Mexican vehicles as for the California Fleet.

In all likelihood, the Mexican plated vehicles coming across the border are likely to be higher in emissions, even for the same model year as a California based vehicle. Until a full-fledged, functioning smog check program is in place, this is likely to remain the case. Therefore, CARB

---

[41] 1st Workshop for Building Verification of Vehicle Regulations in the States of the Northern Border of Mexico Tijuana, Baja California, Mexico, November 13-14, 2014

should pursue a path to adjust the emission rate at the model year level. This would probably be best accomplished with an RSD program. License plate reader would need to distinguish between a Mexican plated vehicle and California plated vehicle. Assuming this can be accomplished, the adjustment factor would simply be the ratio of the mean emissions of the Mexican plated vehicles over the main emissions of the California/US plated vehicles. The license plate reader data would also be used to determine the age distribution so that can be shifted within EMFAC for the border regions.

4.3.1.5. UNREGISTERED VEHICLES

During the EMFAC2014 workshops, one concern expressed by stakeholders was EMFAC's handling of unregistered vehicles. CARB has found that most unregistered vehicles are temporarily unregistered. As discussed in Section 4.2, CARB identifies pending vehicles. These vehicles are not registered but have some sort of activity indicating the owner intends to register them (partial fees paid, omission of smog check certificate, etc.). CARB counts these vehicles as being active if they register within six months. These vehicles are technically unregistered but are treated as registered vehicles. CARB's most recent estimate is that these vehicles comprise approximately 2.2 percent of the fleet. Any vehicles pending for more than six months are assumed to have been retired or have otherwise left the California fleet. Any of these vehicles pending for more than six months are not counted in EMFAC. Arguably, these chronically unregistered vehicles should be accounted for.

Out of approximately 28 million vehicles, 320,000 pending vehicles have still not registered after six months. This means that 1.1 percent of the vehicles have either been retired, left the state or are driving around chronically unregistered. Because these vehicles could have very high emissions, staff investigated the chronically unregistered fraction of the fleet. In calendar year 2000, Durbin found that approximately 0.98 percent[42] of the fleet was unregistered for more than three months. However, this study was 17 years ago and may not be representative of today's fleet.

To analyze the chronically unregistered fraction in a more contemporary sense, CARB staff analyzed Remote Sensing Data from calendar years 2013 and 2015 from La Brea Blvd in Los Angeles. As indicated in Figure 4.3-52, 0.44 – 0.92 percent of the fleet appear to be chronically unregistered at any one time. This is in reasonable agreement with Durbin, et al. These vehicles have two influences on the fleet: their activity, and their emission rates.

Excluding chronically unregistered vehicles arguably reduces the fleet by something less than 1 percent. However, these vehicles are likely older and in attempting to avoid municipal enforcement agencies, probably contribute little to the VMT. Additionally, EMFAC adjusts VMT to either fuel sales or MPO activity, so arguably the VMT is captured implicitly. However, if there is a significant age distribution difference this could affect the distribution by age and

[42] Thomas Durbin, Theodore Younglove, Carrie Malcolm, Matthew R. Smith, Determination of Non-Registration Rates for On-Road Vehicles in California", 2001

technology, and therefore the emissions. Figure 4.3-53 indicates that the chronically unregistered fleet has a significantly larger fraction of vehicles in the 1995-2005 model year (10 to 15 years old) than the fleet as a whole.

Figure 4.3-52: Chronically Unregistered Vehicle Fraction

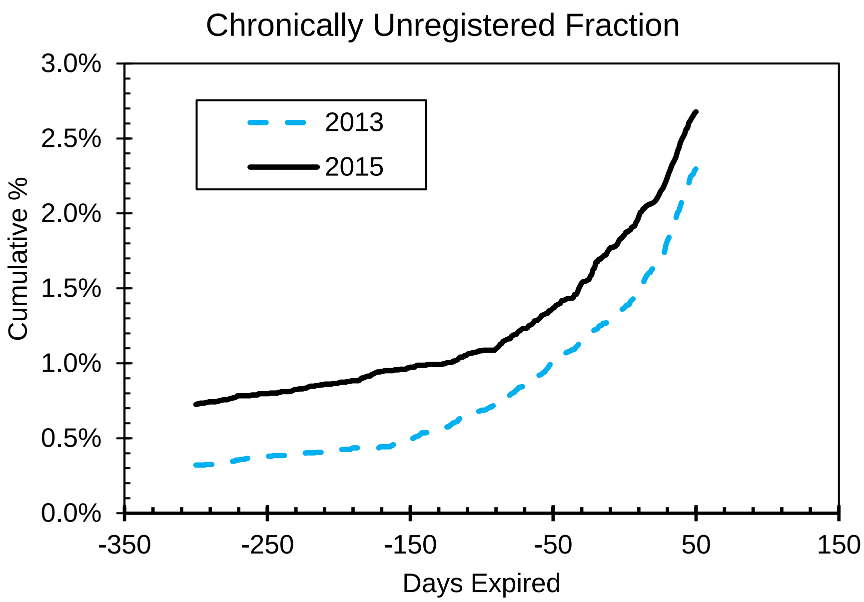
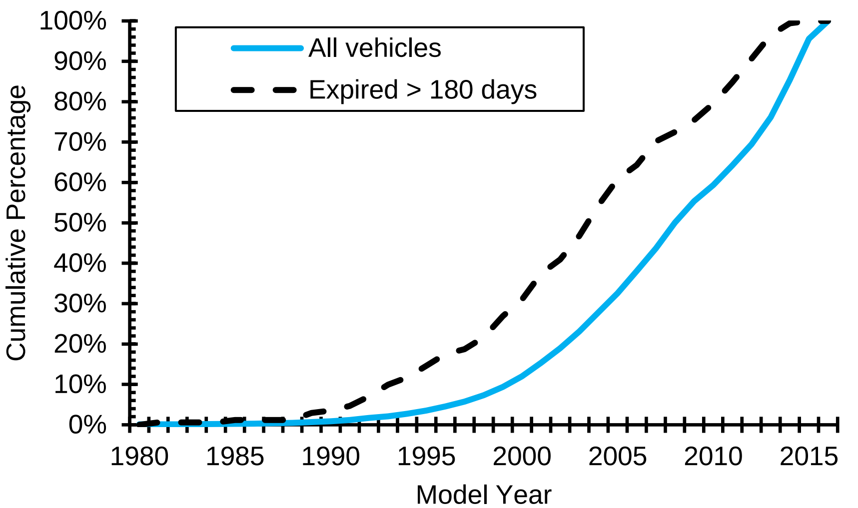


Figure 4.3-53: Age Distribution Comparison between the whole fleet and vehicles that have registration expiration more than 180 days.



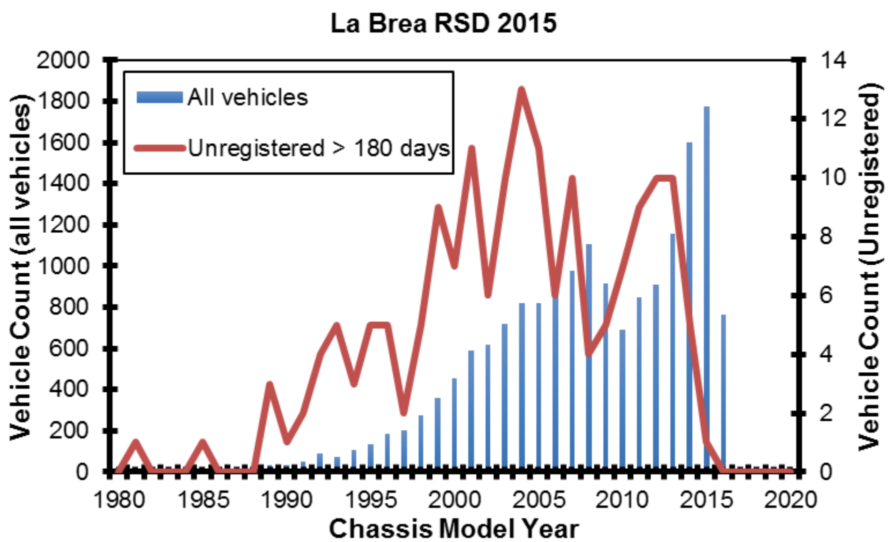
In terms of emission rates, CARB staff compared RSD emission rates for chronically unregistered vehicles and the fleet as a whole for the 2015 La Brea campaign in Table 4.3-37. Staff initially considered using these emission rates to create adjustment factors for the fleet, however, this adjustment would only be good for calendar year 2015. To be able to forecast and backcast, it would be necessary to make the adjustment at the model year level. Staff examined the fleet by model year to see if there would be adequate data to make model year adjustments.

Table 4.3-37: Chronically Unregistered Vehicle Emission Rates

	Expired for > 180 days	All others
Chassis MY	2002.4 +- 0.5	2006.9 +- 0.0
CO (g/kg fuel)	41.3 +- 7.4	12.7 +- 0.4
HC (g/kg fuel)	3.3 +- 0 .7	1.2 +- 0.1
NOx (g/kg fuel)	6.5 +- 1.1	2.5 +- 0.1

As indicated in Figure 4.3-54, there is typically less than 10 vehicles per model year for the chronically unregistered fleet. The chronically unregistered fleet as a whole has fairly high standard error values. The standard error values would likely be very large by model year. At this time, CARB does not believe we have sufficient information to adjust for chronically unregistered vehicles.

Figure 4.3-54: Fleet Distribution by Model Year



In terms of our future directions, RSD technology is a promising technique to make adjustments for chronically unregistered vehicles operating in the fleet. The La Brea campaigns typically yield 20,000 vehicles, which is slightly inadequate for model year characterization. There are additional concerns such as how representative is La Brea for chronically unregistered vehicles? The La Brea site is at a freeway on-ramp, which may be biased against chronically unregistered vehicles trying to avoid the CHP. CARB should consider expanding RSD data collection to not only collect more vehicles, but probably in two or three other areas based upon socioeconomics. Perhaps an analysis of existing automated license plate readers (ALPR) data could be analyzed on a large-scale to address unregistered rates in different areas of the state. From this data, regions could be targeted with RSD to gather the appropriate emissions.

4.3.1.6. LIGHT DUTY VEHICLE TECHNOLOGY GROUP FRACTIONS

EMFAC2017 is being updated to reflect the latest available information on technology group fractions. In a general sense, the technology group fractions are the strategy by which the manufacturers certify their light duty gasoline fleet to meet California standards. The 2006 – 2015 update reflects staff analysis of what was sold in California based upon manufacturers reporting (i.e. NMOG reports). 2016 and newer technology groups were projections by CARB staff as their best estimate as to how the manufacturers will meet future certification standards. Table 4.3-38 defines the technology groups currently used by EMFAC2014. Table 4.3-39 shows the technology groups for EMFAC2017. The color shading is meant to represent the source of the data - either NMOG reports or CARB's Midterm Review

The technology fractions for model years 2006 through 2015 were modified using NMOG reports submitted by manufacturers to the CARB. However, the certification categories supplied by the manufacturers do not always match the EMFAC definitions. CARB staff made some simplifications based upon what was supplied by manufacturers. This is indicated in Table 4.3-40.

For model years 2016 and later, staff relied on projections made by CARB regulatory staff. This input is based upon analyses conducted as part of the CARB Advanced Clean Cars (ACC) Midterm Review[43]. One outcome of this review is two new certification paths that were not anticipated previously and are not reflected in EMFAC2014. Specifically, these new certification paths include federal categories Bin 325 and Bin 110. Bin 325 is a LDT2 Tier 2 bin 8 category allowed to certify in California[44] and Bin 110 is a transitional Tier 3 Bin[45].

[43] https://www.arb.ca.gov/msprog/acc/acc-mtr.htm
[44] https://www.dieselnet.com/standards/us/ld_t2.php
[45] https://www.dieselnet.com/standards/us/ld_t3.php

Table 4.3-38: EMFAC2014 Gasoline Technology Group Fractions

PC/LDT1 Model Year	LEV 160 TG28	L1LEV TG23	L1ULEV TG24	ULEV 125 TG29	SULEV TG30	ULEV 70 TG44	ULEV 50 TG39	SULEV30/PZEV TG31	ATPZEV TG37	SULEV 20 TG38
2006	35.00%	0.00%	0.00%	45.20%	3.43%	0.00%	0.00%	13.52%	2.85%	0.00%
2007	29.00%	0.00%	0.00%	41.49%	2.00%	0.00%	0.00%	25.01%	2.50%	0.00%
2008	18.21%	0.00%	0.00%	48.97%	0.50%	0.00%	0.00%	32.32%	0.00%	0.00%
2009	12.00%	0.00%	0.00%	61.70%	0.30%	0.00%	0.00%	26.00%	0.00%	0.00%
2010	5.01%	0.00%	0.00%	73.95%	0.00%	0.00%	0.00%	21.04%	0.00%	0.00%
2011	5.01%	0.00%	0.00%	73.95%	0.00%	0.00%	0.00%	21.04%	0.00%	0.00%
2012	5.06%	0.00%	0.00%	74.01%	0.00%	0.00%	0.00%	20.93%	0.00%	0.00%
2013	5.06%	0.00%	0.00%	73.81%	0.00%	0.00%	0.00%	21.13%	0.00%	0.00%
2014	5.06%	0.00%	0.00%	73.71%	0.00%	0.00%	0.00%	21.23%	0.00%	0.00%
2015	5.10%	0.00%	0.00%	64.49%	0.00%	8.27%	0.00%	22.14%	0.00%	0.00%
2016	3.07%	0.00%	0.00%	51.53%	0.00%	23.31%	0.00%	22.19%	0.00%	0.00%
2017	3.07%	0.00%	0.00%	38.65%	0.00%	36.20%	0.00%	22.19%	0.00%	0.00%
2018	0.00%	0.00%	0.00%	26.04%	0.00%	48.54%	0.00%	25.42%	0.00%	0.00%
2019	0.00%	0.00%	0.00%	14.59%	0.00%	58.68%	0.00%	26.73%	0.00%	0.00%
2020	0.00%	0.00%	0.00%	2.17%	0.00%	64.35%	0.00%	27.93%	0.00%	5.43%
2021	0.00%	0.00%	0.00%	0.00%	0.00%	33.81%	31.26%	29.38%	0.00%	5.54%
2022	0.00%	0.00%	0.00%	0.00%	0.00%	6.78%	51.19%	30.73%	0.00%	11.30%
2023	0.00%	0.00%	0.00%	0.00%	0.00%	5.75%	36.48%	46.26%	0.00%	11.51%
2024	0.00%	0.00%	0.00%	0.00%	0.00%	3.04%	17.54%	47.25%	0.00%	32.16%
2025	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	66.51%	0.00%	33.49%

LDT2 Model Year	LEV 160 TG28	L1LEV TG23	L1ULEV TG24	ULEV 125 TG29	SULEV TG30	ULEV 70 TG44	ULEV 50 TG39	SULEV30/PZEV TG31	ATPZEV TG37	SULEV 20 TG38
2006	43.00%	0.00%	0.00%	50.00%	3.80%	0.00%	0.00%	3.20%	0.00%	0.00%
2007	34.20%	0.00%	0.00%	59.40%	3.40%	0.00%	0.00%	3.00%	0.00%	0.00%
2008	24.20%	0.00%	0.00%	71.40%	2.30%	0.00%	0.00%	2.10%	0.00%	0.00%
2009	12.00%	0.00%	0.00%	12.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2010	4.00%	0.00%	0.00%	96.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2011	4.00%	0.00%	0.00%	96.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2012	4.00%	0.00%	0.00%	96.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2013	4.00%	0.00%	0.00%	96.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2014	4.00%	0.00%	0.00%	96.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2015	5.00%	0.00%	0.00%	81.20%	0.00%	13.80%	0.00%	0.00%	0.00%	0.00%
2016	5.00%	0.00%	0.00%	76.00%	0.00%	19.00%	0.00%	0.00%	0.00%	0.00%
2017	5.00%	0.00%	0.00%	52.90%	0.00%	42.10%	0.00%	0.00%	0.00%	0.00%
2018	5.00%	0.00%	0.00%	52.80%	0.00%	42.20%	0.00%	0.00%	0.00%	0.00%
2019	5.00%	0.00%	0.00%	42.30%	0.00%	52.70%	0.00%	0.00%	0.00%	0.00%
2020	5.00%	0.00%	0.00%	36.40%	0.00%	58.60%	0.00%	0.00%	0.00%	0.00%
2021	4.00%	0.00%	0.00%	24.10%	0.00%	71.90%	0.00%	0.00%	0.00%	0.00%
2022	4.00%	0.00%	0.00%	23.70%	0.00%	45.00%	27.30%	0.00%	0.00%	0.00%
2023	4.00%	0.00%	0.00%	5.00%	0.00%	45.00%	30.00%	16.00%	0.00%	0.00%
2024	3.00%	0.00%	0.00%	0.00%	0.00%	20.40%	50.00%	26.60%	0.00%	0.00%
2025+	2.00%	0.00%	0.00%	0.00%	0.00%	0.00%	25.60%	72.40%	0.00%	0.00%

MDV Model Year	LEV 160 TG28	L1LEV TG23	L1ULEV TG24	ULEV 125 TG29	SULEV TG30	ULEV 70 TG44	ULEV 50 TG39	SULEV30/PZEV TG31	ATPZEV TG37	Tier 2 TG34
2006	93.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.00%
2007	72.00%	0.00%	0.00%	28.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2008	48.00%	0.00%	0.00%	52.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2009	30.00%	0.00%	0.00%	70.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2010	15.00%	0.00%	0.00%	85.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2011	15.00%	0.00%	0.00%	85.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2012	15.00%	0.00%	0.00%	85.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2013	15.00%	0.00%	0.00%	85.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2014	15.00%	0.00%	0.00%	85.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2015	5.10%	0.00%	0.00%	81.00%	0.00%	13.80%	0.00%	0.00%	0.00%	0.00%
2016	5.10%	0.00%	0.00%	75.80%	0.00%	19.10%	0.00%	0.00%	0.00%	0.00%
2017	5.10%	0.00%	0.00%	52.80%	0.00%	42.10%	0.00%	0.00%	0.00%	0.00%
2018	5.10%	0.00%	0.00%	52.70%	0.00%	42.20%	0.00%	0.00%	0.00%	0.00%
2019	5.10%	0.00%	0.00%	42.30%	0.00%	52.60%	0.00%	0.00%	0.00%	0.00%
2020	5.10%	0.00%	0.00%	36.40%	0.00%	58.40%	0.00%	0.00%	0.00%	0.00%
2021	4.00%	0.00%	0.00%	24.10%	0.00%	71.90%	0.00%	0.00%	0.00%	0.00%
2022	4.00%	0.00%	0.00%	23.70%	0.00%	45.00%	27.30%	0.00%	0.00%	0.00%
2023	4.00%	0.00%	0.00%	5.00%	0.00%	45.00%	30.00%	16.00%	0.00%	0.00%
2024	3.00%	0.00%	0.00%	0.00%	0.00%	20.40%	50.00%	26.60%	0.00%	0.00%
2025+	2.00%	0.00%	0.00%	0.00%	0.00%	0.00%	25.60%	72.40%	0.00%	0.00%

Table 4.3-39: EMFAC 2017 Gasoline Technology Group Fractions

PC/LDT1 Model Year	LEV 160 TG28	L1LEV TG23	L1ULEV TG24	ULEV 125 TG29	ULEV 70 TG44	ULEV 50 TG39	SULEV30/PZEV TG31	SULEV 20 TG38	Data Source
2006	23.00%	5.70%	3.90%	46.80%	0.00%	0.00%	20.70%	0.00%	NMOG Report
2007	20.80%	0.00%	0.00%	47.60%	0.00%	0.00%	31.60%	0.00%	
2008	21.84%	0.00%	0.00%	40.98%	0.00%	0.00%	37.17%	0.00%	
2009	10.80%	0.00%	0.00%	49.12%	0.00%	0.00%	40.02%	0.00%	
2010	8.00%	0.00%	0.00%	48.72%	0.00%	0.00%	43.22%	0.00%	
2011	5.66%	0.00%	0.00%	58.24%	0.00%	0.00%	36.10%	0.00%	
2012	5.43%	0.00%	0.00%	50.45%	0.00%	0.00%	44.02%	0.00%	
2013	3.04%	0.00%	0.00%	49.49%	0.00%	0.00%	47.47%	0.00%	
2014	1.72%	0.00%	0.00%	53.69%	0.30%	0.00%	43.07%	1.11%	
2015	3.06%	0.00%	0.00%	47.60%	4.19%	0.00%	44.64%	0.51%	
2016	2.41%	0.00%	0.00%	46.66%	6.58%	0.00%	44.35%	0.00%	CARB Staff Projections
2017	2.41%	0.00%	0.00%	46.66%	6.58%	0.00%	44.35%	0.00%	
2018	2.36%	0.00%	0.00%	35.46%	18.28%	0.00%	43.90%	0.00%	
2019	0.00%	0.00%	0.00%	28.23%	27.31%	0.00%	44.45%	0.00%	
2020	0.00%	0.00%	0.00%	19.68%	27.43%	7.64%	45.25%	0.00%	
2021	0.00%	0.00%	0.00%	13.63%	27.52%	8.16%	45.60%	5.09%	
2022	0.00%	0.00%	0.00%	8.75%	27.64%	7.37%	46.01%	10.23%	
2023	0.00%	0.00%	0.00%	1.72%	27.76%	7.02%	53.23%	10.27%	
2024	0.00%	0.00%	0.00%	0.00%	18.98%	1.46%	58.93%	20.63%	
2025	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	73.28%	26.72%	

LDT2/MDV Model Year	LEV 160 TG28	L1LEV TG23	L1ULEV TG24	ULEV 125 TG29	ULEV 70 TG44	ULEV 50 TG39	SULEV30/PZEV TG31	SULEV 20 TG38	Data Source
2006	42.70%	0.01%	3.90%	48.90%	0.00%	0.00%	4.40%	0.00%	NMOG Report
2007	25.70%	0.00%	0.00%	59.70%	0.00%	0.00%	14.60%	0.00%	
2008	22.80%	0.00%	0.00%	65.01%	0.00%	0.00%	12.20%	0.00%	
2009	20.50%	0.00%	0.00%	72.21%	0.00%	0.00%	7.30%	0.00%	
2010	7.10%	0.00%	0.00%	72.10%	0.00%	0.00%	20.80%	0.00%	
2011	9.10%	0.00%	0.00%	71.90%	0.00%	0.00%	18.90%	0.00%	
2012	5.80%	0.00%	0.00%	67.73%	0.00%	0.00%	26.41%	0.00%	
2013	6.70%	0.00%	0.00%	83.50%	0.00%	0.00%	9.80%	0.00%	
2014	5.80%	0.00%	0.00%	86.51%	0.00%	0.00%	7.70%	0.00%	
2015	1.71%	0.00%	0.00%	89.80%	1.80%	0.00%	6.70%	0.00%	
2016	2.12%	0.00%	0.00%	82.52%	8.90%	0.02%	6.43%	0.00%	CARB Staff Projections
2017	2.12%	0.00%	0.00%	82.52%	8.90%	0.02%	6.43%	0.00%	
2018	2.12%	0.00%	0.00%	74.29%	16.79%	0.02%	6.78%	0.00%	
2019	2.13%	0.00%	0.00%	54.52%	36.00%	0.02%	7.32%	0.00%	
2020	2.14%	0.00%	0.00%	36.76%	38.20%	10.97%	11.94%	0.00%	
2021	2.15%	0.00%	0.00%	24.45%	38.44%	16.97%	17.99%	0.00%	
2022	2.16%	0.00%	0.00%	12.23%	30.57%	29.73%	25.32%	0.00%	
2023	2.17%	0.00%	0.00%	5.11%	20.44%	36.43%	35.85%	0.00%	
2024	2.17%	0.00%	0.00%	0.00%	10.25%	38.08%	49.50%	0.00%	
2025	2.05%	0.00%	0.00%	0.00%	0.00%	32.70%	65.25%	0.00%	

Table 4.3-40: EMFAC2017 Technology Group Mapping and Manufacturer Defined

MY Range	EMFAC	Manufacturer Definitions
2006-2013	LEV	L1LEV, L2LEV
2006-2013	ULEV	L1ULEV, L2ULEV
2006-2013	SULEV	L1SULEV, L2SULEV
2014-2015	SULEV20	SULEV20, SULEV 20
2014-2015	SULEV30	L2SULEV, PZEV (L2SULEV +150 K), L3SULEV30)
2014-2015	ULEV70	L3ULEV70
2014-2015	ULEV125	L3ULEV125, L2ULEV
2014-2015	LEV160	L2LEV, L3LEV160

Bin 325 is only expected to have 0.05 percent of the LDT2 fleet in model years 2016 and 2017. Because of this small influence, CARB is going to assume this to be zero for the purposes of EMFAC. Bin 110 is assumed to be equivalent to CARB ULEV125, which is the current practice for vehicles certifying in California. Therefore, these two federal categories are now grouped into the EMFAC categories. A summary of findings is now provided below:

MY 2006-2015 (based upon NMOG data):

PC/LDT1 - The actual technology group distributions to be used in EMFAC2017 are not significantly different from EMFAC2014 predictions. In general, however, it appears that fewer ULEV125s were produced then predicted by EMFAC2014, and more SULEV30/PZEVs are produce than expected.

LDT2 - EMFAC2014 predicted that the dominant path to certification would be ULEV125s. Although this was the path for most vehicles, many still opted to make LEV160s, offset with some SULEV/PZEVs.

MDV - The NMOG data show a faster transition to the ULEV125s than originally anticipated.

MY 2016-2025 (based upon Midterm Review):

PC/LDT1 - In EMFAC2014, it was assumed that the ULEV50 technology group would be important for 2021-2024 vehicles. CARB now believes that most of the ULEV50s expected will be supplanted with ULEV70s and SULEV/PZEVs.

LDT2 - There aren’t a lot of significant differences between EMFAC2014 and EMFAC2017 for LDT2s. The biggest difference is probably in EMFAC2017 assuming an earlier implementation of ULEV50 and SULEV/PZEVs.

MDV - The midterm review projects a much quicker adoption of the ULEV50 pathway.

These updates to the technology fractions will generally not have a large effect on emissions. Since model year specific fleet average requirements are unchanged, this simply reflects a different pathway to the same goal. However, there are projected to be some significant changes in the penetration of ZEVs. Future penetration of ZEVs is addressed in section 4.5.4.

4.3.2. UPDATES TO HD EMISSION RATES

4.3.2.1. RUNNING EXHAUST EMISSION RATES (TRUCKS)

In EMFAC, the base emission rate (BER) of a pollutant for a given model year (MY) of heavy-duty (HD) trucks is calculated using the following equation:

$$BER_{odo} = (ZMR + DR \times Odo) \qquad \text{(Eq. 4.3-7)}$$

where ZMR is zero-mile emission rate and DR emission deterioration rate; and Odo is the average odometer of all trucks of that model year.

ZMR and DR are typically developed on a model year group basis, with each group including several consecutive model years that usually share the same emission standards and/or emission control technology. Thus, from the chassis dynamometer test data of all tested vehicles from a given model year group, an average emission rate (ER_{avg}) and an average odometer (Odo_{avg}) are first calculated, and using the ER_{avg} and Odo_{avg}, the ZMR and DR for the group are then calculated from the following equations:

$$ZMR = ER_{avg} \,/\, \left(1 + EIR \times Odo_{avg}\right) \qquad \text{(Eq. 4.3-8)}$$

$$DR = \left(ER_{avg} - ZMR\right) \,/\, Odo_{avg} \qquad \text{(Eq. 4.3-9)}$$

where EIR is emission impact rate, which is used in EMFAC to quantify the emission deterioration of HD trucks.

A basic assumption in assessing emission deterioration of HD trucks is that emissions from engines remain stable in the absence of tampering, mal-maintenance, and malfunction (TM&M)[46]. To estimate the emission impact of TM&M, a methodology was developed that identifies a number of specific types of TM&M affecting the average emissions of a truck fleet. The EIR is the product of frequency of occurrence of TM&M and the emission increases over the baseline level caused by the TM&M.

The BER calculated from Eq. 4.3.7 is scaled by speed correction factors (SCF) to obtain emission rates at various speeds, which are then combined with vehicle miles travelled (VMT) at different speeds to estimate the running exhaust emissions of a pollutant from HD trucks. SCF are developed from chassis dynamometer test data obtained by testing trucks over several test cycles that have different average cycle speeds. The following sections discuss the analysis of chassis dynamometer test data, revision to TM&M frequency and emission increase caused by TM&M, and calculations of ZMR, DR, and SCF for the 2010-2012 and 2013+ MY groups of HD diesel trucks.

---

[46] Detailed description can be found in EMFAC2007 technical document: Revision of Heavy Heavy-Duty Diesel Truck Emission Factors and Speed Correction Factors: Appendix C.

4.3.2.1.1. EMISSION TEST DATA

The emissions data for updating ZMR and DR for HD diesel trucks were obtained from several sources. The primary data source is CARB's Truck and Bus Surveillance Program (TBSP), which was designed to collect in-use emissions data for improving the emissions inventory of HD vehicles, among other objectives. To date, a total of 20 heavy heavy-duty trucks (Class 8) have been tested, and test data are summarized in Appendix 6.5.

Another source of data is a testing project initiated by the Engine and Truck Manufacturers Association (EMA), which contracted the University of California, Riverside (UCR) to test five late model heavy-duty diesel trucks. As a collaborative effort, CARB's Heavy-Duty Vehicle Laboratory at the Los Angeles Metropolitan Transit Agency (MTA) also tested three of the five trucks, mainly for the purpose of understanding emissions variability of trucks equipped with SCR and DPF. The test data from the EMA-UCR and CARB testing projects are listed in Appendix 6.6.

All test vehicles in the EMA-UCR, CARB MTA, and CARB TBSP testing were tested on a dynamometer over the Urban Dynamometer Driving Schedule (UDDS) as well as several other test cycles to obtain emission rates at different speeds for speed correction factor calculations (to be discussed in a later section). Table 4.3-41 lists the characteristic parameters of the cycles as well as the projects they were used.

Table 4.3-41: Test cycles used in dynamometer testing of HD trucks

Test Cycle/Mode	Average Speed (mph)	Duration (sec)	Length (mi)	Testing Project/Program
UDDS	18.8	1060	5.54	EMA-UCR, MTA, TBSP
Creep	1.8	253	0.12	EMA-UCR, MTA, TBSP
Near Dock Drayage	6.6	3,046	5.59	TBSP
Local Drayage	9.3	3,362	8.70	TBSP
Transient	15.4	668	2.85	EMA-UCR, MTA
40-mph Cruise	39.9	2,083	23.1	EMA-UCR, MTA, TBSP
50-mph Cruise	50.2	757	10.5	EMA-UCR, MTA
62-mph Cruise	62.0	1,385	23.2	TBSP

4.3.2.1.2. REVISION OF TM&M FREQUENCY AND EMISSION INCREASE

In EMFAC2007, staff developed the TM&M frequencies and associated emission increases for selective catalytic reduction (SCR) systems and diesel particulate filter (DPF)[47] and continued to use them for calculating truck emission rates in EMFAC2011 and EMFAC2014. For EMFAC2017, staff has reviewed the information and data available regarding the in-use performance of SCR and DPF on a fleet-wide basis and made revisions when deemed necessary.

[47]A detailed description can be found in EMFAC2007 technical document: Revision of Heavy Heavy-Duty Diesel Truck Emission Factors and Speed Correction Factors, Appendix C.

Frequency of NO_X related TM&M categories

There are on-going efforts both within and outside CARB to examine the TM&M frequency of NO_X related components. For EMFAC2014 staff re-evaluated the values of frequency of NO_X related TM&M categories for HD diesel trucks and concluded that in general they remain largely consistent with the in-use emissions test data. For EMFAC2017, staff made an adjustment to the frequency of all NO_X related TM&M categories for 2010+ MY. Although the regulatory emission warranty for Classes 4-8 HD trucks are 100,000 miles, some of the engines have an extended warranty up to their regulatory useful life depending on vehicle class and type of service[48]. This in effect lowers the rate of occurrence of emission component mal-function or failure for the extended warranty periods and thus a reduction in the TM&M frequency. As a result, staff first estimated weighted average warranty mileages for both heavy heavy-duty (GVWR ≥33,001 lbs.) and medium heavy-duty (GVWR 14,001 – 33,000 lbs.) vehicles and then applied the TM&M frequency at 100,000 miles to these two weighted average mileages, with frequency values at other mileages adjusted accordingly. Table 4.3-42 compares the revised TM&M frequency values in EMFAC2017 versus those in EMFAC2014.

Table 4.3-42: Frequency of NO_X related TM&M at 1,000,000 Miles for HD Trucks

TM&M Category	EMFAC2014			EMFAC2017		
	2007-09	2010-12 MY	2013+ MY	2007-09 MY	2010-12 MY	2013+ MY
NO_X Sensor	n/a	45%	30%	n/a	36%	24%
Replacement NO_X Sensor	n/a	2.3%	1.5%	n/a	1.8%	1.2%
SCR System	n/a	50%	33%	n/a	40%	27%
EGR Disabled / Low Flow	n/a	20%	13%	10%	16%	11%

* TM&M frequency was not estimated for the 2007-2009 MY in EMFAC2014. See text for the discussion.

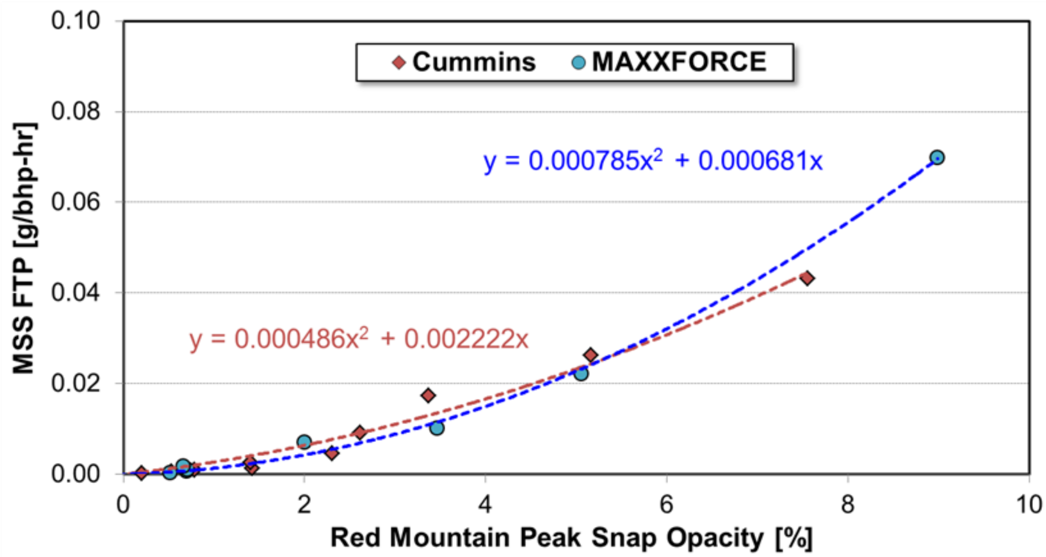
Staff also changed the way the 2007-2009 MY deterioration is estimated. Up until EMFAC2014, it had been assumed that for the 2007-2009 MY, the 50 percent phase-in for the 2010 NO_X standard of 0.2 g/bhp-hr would be achieved with a mix of EGR and SCR engines. Based on that assumption, the NO_X deterioration rate for the 2007-2009 was estimated by taking a 50 percent /50 percent weighted average of the deterioration rates of 2003-2006 MY and 2010-2012 MY groups. However, certification data show that engine manufacturers met the phase-in requirements largely with enhanced EGR and certified most engines to a NO_X level around 1.2 g/bhp-hr. As a result, NO_X emission deterioration for the 2007-2009 MY group was independently determined. For enhanced EGR, a frequency was estimated for the "EGR Disabled / Low Flow" category by taking half of the value used for the 2010-2012 MY group, as shown in Table 4.3-42.

[48] According to data from a survey sponsored by CARB, 40% of Classes 4-8 trucks have emission warranty to their respective engine useful life, and based on data from engine manufacturers a majority of the remaining 60% of Class 8 trucks have emission warranty to 250,000 miles.

Frequency of PM related TM&M categories

Staff revised the frequencies of DPF related TM&M based on the data collected in CARB's roadside opacity testing under the Heavy-Duty Vehicle Inspection Program and Periodic Smoke Inspection Program. In order to use the roadside smoke test data to determine the DPF TM&M frequencies, opacity readings were related to PM emission levels using data from a study conducted by the National Renewable Energy Laboratory (NREL)[49]. In the study, the channel end caps in the DPF of a 2008 MaxxForce engine and the DPF of a 2011 Cummins engine were progressively milled off to simulate different levels of filter leaking, and for each simulated level of leaking the opacity and the PM emissions were measured. Results of the filter leaking simulation experiment are summarized in Figure 4.3-55. From the two regression curves it can be estimated that the PM emission standard (0.01 g/bhp-hr) would be equivalent to a corrected opacity reading of 3.2 percent for the MaxxForce and 2.8 percent for the Cummins. Staff has assumed that the 3.2 percent and 2.8 percent opacity levels apply to all 2007-2009 MY engines and 2010+ MY engines, respectively.

Figure 4.3-55: Relationship between FTP PM emissions and opacity reading as established in a NREL study in which the channel end caps in a DPF were progressively milled to simulate DPF leaking (MSS stands for micro-soot sensor)



In analyzing the roadside smoke test data, a DPF was considered to be leaking if it had an opacity reading greater than 3.2 percent for a 2007-2009 MY engine and 2.8 percent for a 2010+ MY engine. With these opacity limits, the CARB roadside smoke test data were analyzed and the fractions of over-limit opacity readings as a function of odometers shown in Figure 4.3-56. For the 2007-09 MY, data points were grouped into odometer bins of 100,000 miles. However, for the 2010+ MY, because of the much fewer data points than the 2007-2009 MY

---

[49] Aerodynamic Drag Reduction Technologies Testing of Heavy-Duty Vocational Vehicles and a Dry Van Trailer: Appendix C - Heavy-Duty On-Road Vehicle Opacity and Engine Repair Durability, Technical Report NREL/TP-5400-64610, National Renewable Energy Laboratory, 2016.

group, larger bins were used for higher odometers; in particular, the data points for all trucks with an odometer reading >500,000 miles were combined into a single bin because only a very small number of high mileage 2010+ MY trucks were captured in the three roadside studies.

Figure 4.3-56: Fraction of trucks with opacity readings at or greater than 3.2% (2007-09 MY) or 2.8% (2010+ MY) for different odometer bins. The data were collected from CARB roadside smoke inspection campaigns conducted in 2011, 2014, and 2016.

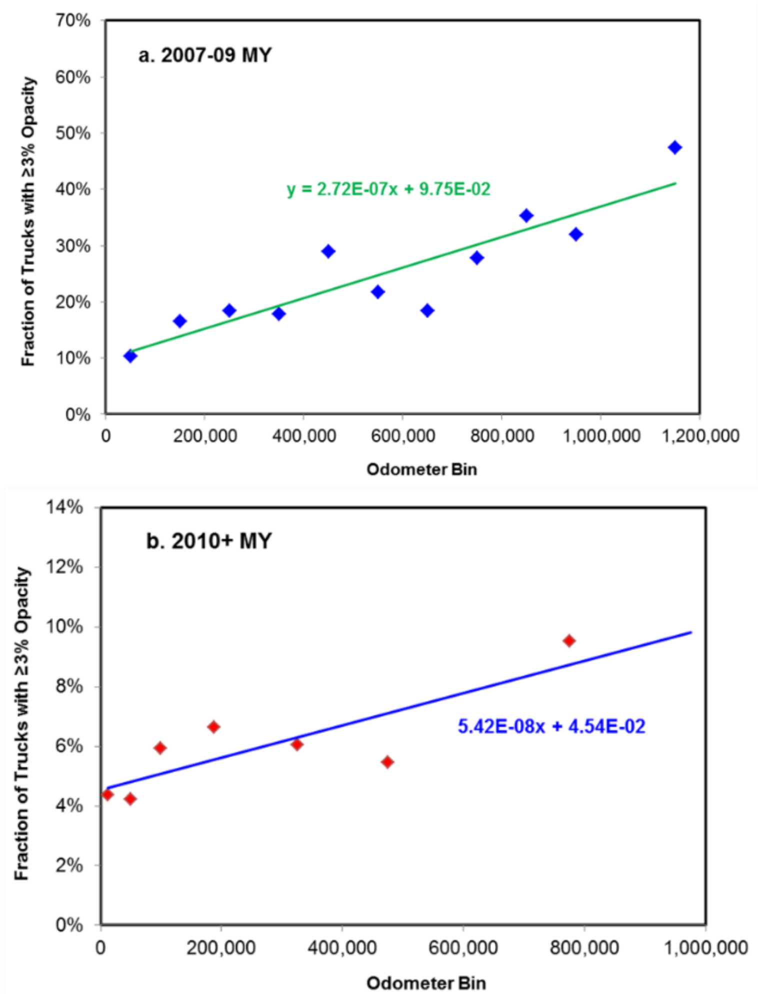


Figure 4.3-56 shows that there is a positive correlation between the fraction of over limit opacity readings and odometer, suggesting that the fraction of leaking DPFs should also be correlated with truck mileages. The fitted linear line based on 2007-2009 MY data gives a frequency of 38 percent at 1 million miles (Figure 4.3-56, a), which is similar to the 37.6 percent frequency of the DPF Leaking category for 2007-2009 MY group in EMFAC2014, as can be seen in Table 4.3-42. In contrast, the fitted 2010+ MY data yields a frequency of 10 percent (Figure 4.3-56, b),

much lower than the 37.6 percent used in EMFAC2014 (Table 4.3-43)[50]. Based on the roadside smoke test data, staff revised the frequency for the DPF leaking category to 38 percent for the 2007-2009 MY and 10 percent for the 2010+ MY, as shown in Table 4.3-43.

Table 4.3-43: Frequency of Leaking and Disabled DPF at 1,000,000 Miles for HD Trucks

DPF Related TM&M	EMFAC2014			EMFAC2017		
	2007-09 MY	2010-12 MY	2013+ MY	2007-09 MY	2010-12 MY	2013+ MY
DPF Leaking	37.6%	37.6%	26.3%	38%	10%	6.7%
DPF Disabled	2%	2%	1.3%	0%	0%	0%

Historically, EMFAC assumes that a small percentage (~2 percent) of the fleet have a disabled filter due to tampering. However, in CARB's recent roadside smoke inspections of DPF-equipped HD trucks, inspectors were not able to differentiate between tampered DPFs and leaky DPFs on the tested fleet. A disabled DPF would act as a completely damaged DPF in terms of its opacity reading and should be captured in the opacity database. Thus, since the roadside smoke inspection data can include vehicles with a disabled DPF and a leaky DPF, staff decided to eliminate "DPF disabled" as a separate DPF TM&M category, as shown in Table 4.3-43.

It should be noted that staff is taking initiative to take advantage of on-board diagnostics (OBD) available on MY2013 and newer engines to update TM&M frequencies in the near future. With the introduction of on-board diagnostics (OBD), it is now possible to monitor the performance and malfunction of various engine components and after-treatment systems using a simple computer interface. By monitoring and evaluating the various components and systems, the on-board computer is able to determine the presence of a malfunction that can affect emissions and illuminate the "Check Engine" or "Service Engine Soon" light (also known as the malfunction indicator lamp or MIL) on the dashboard. In some instances, the computer software may identify a problem before there is an overt indication to the vehicle operator. The combination of the various emission control and engine components/systems, the MIL, and the diagnostic computer software make up the OBD system. By using commercially available scan tools, it is possible to connect to vehicles engine control unit (ECU) and download this diagnostic data from MY 2013 and newer HDDT engines.

Staff will be collecting this data on a voluntary basis from field utilizing enforcement field staff. In addition, a contract is currently being put in place to collect OBD data from repair shops, truck stops and other locations within the State that can provide representative data to update HD truck TM&M frequencies. Staff is anticipating that the utilization of OBD data would lend a change to key TM&M action categories to better reflect current emission-related OBD categories for MY 2013 and newer engines.

[50] The main reason for such a discrepancy is that EMFAC is assuming a PM certification level at the standard (0.01 g /bhp-hr), but the actual certification levels of HD engines have been several times lower. As a result, it takes a significant performance degradation in DPFs to register an opacity reading over the limit equivalent to the PM standard. See text for the discussion on PM emission increase rate revision.

TM&M Emission Increase Rates

In EMFAC, for each TM&M category there is an associated percent emission increase, which quantifies the impact of that TM&M on the overall emissions. Staff reviewed the percent emission increase for the SCR and DPF related TM&M and made necessary updates based on the OBD durability demonstration vehicle (DDV) data submitted by heavy-duty engine manufacturers as part of the HD OBD requirements. This analysis utilized reviewing selected DDV reports from major engine manufacturers from MY2013 to 2016 and arriving at sales weighted emissions increase to simulate the emissions impact resulting from such malfunctions.

For NO_X related TM&M categories, an analysis of the DDV data indicates that overall the DDV reports agree with EMFAC with respect to the increase in NO_X emissions due to mal-function or failure of SCR catalyst and NO_X sensors. Additionally, the emission increase for NO_X sensor failure in EMFAC is ~50 percent lower than the corresponding value presented in the EMA report on truck TM&M categories. Thus, based on the DDV data and EMA report, staff decided to use the emission increase values for all NO_X related TM&M categories in EMFAC2014 for EMFAC2017. For the 2007-2009 MY group, however, a value of 300 percent increase was used for the “EGR Disabled/Low Flow” category, which was derived by doubling the value for the 2010-2012 MY group because of a more efficient NO_X control expected from an enhanced EGR system.

For PM related TM&M categories, up to EMFAC2014 it was assumed that on average a leaking DPF will results in 600 percent increase in PM emissions. This assumption was based on the projection that a leaky DPF would emit around 0.07 g/bhp-hr, which would be 600 percent higher than the PM certification standard of 0.01 g/bhp-hr. However, for computer-controlled SCR-DPF combination systems, engine manufacturers have been able to certify their engines at PM emission levels that are almost 10 times lower than the standard (i.e., 0.001 g/bhp-hr). Therefore, with the new system emissions increases associated with a leaking DPF can approach 6,000 percent because engine-out emissions have remained largely unchanged while PM emission control efficiency can achieve as high as 99.9 percent. Leaking or total failure of a highly efficient DPF would lead to 50-100 times of increase in PM emission rate. Thus, staff revised the PM emission increase for the DPF leaking category to 5,200 percent for the 2010+ MY using the data in the manufacturer DDV reports but decided to leave the rate unchanged for the 2007-2009 MY (Table 4.3-44).

Table 4.3-44: Emission Increases for SCR and DPF Related TM&M Category

TM&M Category	EMFAC2014		EMFAC2017	
	2007-09 MY	2010+ MY	2007-09 MY	2010+ MY
NO_X Sensor	--	200%	--	200%
Replacement NO_X Sensor	--	200%	--	200%
SCR System	--	300%	--	300%
EGR Disabled / Low Flow	150%	150%	300%	150%
DPF Leaking	600%	600%	600%	5,200%

Based on the revised frequencies and emission increases for the SCR and DPF related TM&M, staff revised the EIRs of NO_X and PM for the 2007-2009, 2010-2012 and 2013+ MY HD trucks.

Table 4.3-45 shows a comparison between the EIRs in EMFAC2014 and the revised EIRs for EMFAC2017. Results in the table show that the combined effect of lower frequency and higher emission increase for DPF leaking TM&M category yielded an overall increase in the EIR for 2010-2012 MY and 2013+ MY HD trucks.

Table 4.3-45: PM Emission Impact Rate (EIR) at 1,000,000 Miles for 2010+ MY HD Trucks

Pollutant	EMFAC2014			EMFAC2017		
	2007-09 MY	2010-12 MY	2013+ MY	2007-09 MY	2010-12 MY	2013+ MY
NO_X	113%	357%	220%	42.3%	272%	170%
PM	288%	288%	193%	268%	579%	375%

As stated earlier, with the utilization of OBD data to estimate TM&M frequency, the TM&M actions may change in next EMFAC updates to accurately reflect emissions-related OBD categories with emissions increase provided by the DDV reports. In the future, such a change may also lead to updated methodology to calculate composite EIRs for both PM and NO_x for MY 2013 and newer engines.

4.3.2.1.3. DIESEL TRUCK RUNNING EXHAUST EMISSION RATES

Following the same methodology used in previous EMFAC versions, a sales fraction weighted average ERs were first calculated from the UDDS test data for individual engine MY groups. With the average ERs and T&M impact rates, the HC, CO, NOx, and PM ZMRs and DRs were then calculated for all MY groups. For CO_2, only ZMRs were calculated and a DR of zero was assumed.

The resulting ZMRs and DRs were based on engine MY. However, truck activity data are vehicle MY based. Thus, in order to apply these rates to vehicle activity data for emissions inventory calculations, they had to be adjusted for the mismatch between the vehicle MY and the engine MY. The MY mismatch was adjusted using data from the Drayage Truck Registry (DTR), a CARB administrated database of drayage trucks operating in California. The database includes information on the fractions of different engine MYs within given vehicle MYs. For a given vehicle MY, the ZMR of a pollutant was calculated as the weighted average of the ZMRs of all engine MYs in that vehicle MY, with the fractions of these engine MYs in that vehicle MY used as weighting factors. MY were calculated in the same manner. The HHDDTs vehicle MY based ZMRs and DRs of HC, CO, NOx, PM, and CO_2 are shown in Table 4.3-46.

Emission rates for MHDDT of pre-2006 MYs were based on test data from the Coordinating Research Council E-55/59 project. Only a few late model MHDDT have been tested to date and thus there is not enough test data available to develop MHDDT specific emission rates. As a result, the emission rates for 2010+ MY MHDDT were derived by applying the ratio of 2003-2006 MY HHDTs to 2003-2006 MY MHDDT emission rates to 2010+ MY HHDDT as:

$$\mathrm{ER}_{2007+\ \mathrm{MY\ MHDDT}} = \frac{\mathrm{ER}_{2003-06\ \mathrm{MY\ MHDDT}}}{\mathrm{ER}_{2003-06\ \mathrm{MY\ MHDDT}}} \times \mathrm{ER}_{2007+\ \mathrm{MY\ HHDDT}} \qquad \text{(Eq. 4.3.10)}$$

Table 4.3-46 Revised Zero-Mile Rates (g/mi) and Deterioration Rates (g/mi/10K mi) for Diesel Heavy Heavy Duty Trucks by Vehicle Model Year†

	HC		CO		NOx		PM		CO_2	
Vehicle MY	ZMR	DR	ZMR	DR	ZMR	DR	ZMR	DR	ZMR	DR
Pre 1987	1.506	0.0343	8.043	0.183	22.98	0.019	1.7500	0.0278	2335	0
1987-90	1.183	0.0408	6.317	0.218	22.65	0.026	1.9010	0.0248	2262	0
1991-93	0.864	0.0294	2.899	0.099	19.62	0.039	0.7974	0.0145	2176	0
1994-97	0.641	0.0338	2.150	0.114	19.27	0.046	0.5241	0.0112	2086	0
1998-02	0.652	0.0336	2.190	0.113	18.95	0.053	0.5740	0.0101	2135	0
2003-06	0.546	0.0205	1.201	0.046	13.03	0.052	0.3868	0.0060	2114	0
2007	0.510	0.0167	1.105	0.036	11.47	0.048	0.2886	0.0045	2169	0
2008	0.428	0.0084	1.063	0.021	8.21	0.035	0.0380	0.0009	2343	0
2009	0.425	0.0081	1.062	0.020	8.08	0.034	0.0285	0.0008	2350	0
2010	0.365	0.0070	0.948	0.018	7.29	0.038	0.0247	0.0007	2337	0
2011	0.095	0.0017	0.428	0.007	3.66	0.057	0.0074	0.0003	2281	0
2012	0.019	0.0003	0.283	0.004	2.65	0.063	0.0025	0.0001	2265	0
2013	0.019	0.0003	0.283	0.004	2.65	0.061	0.0025	0.0001	2248	0
2014	0.019	0.0002	0.283	0.003	2.68	0.049	0.0025	0.0001	2129	0
2015+	0.019	0.0002	0.283	0.003	2.68	0.046	0.0025	0.0001	2100	0

† Emission rates are adjusted for pre-clean diesel fuel. These emission rates are corrected using fuel correction factors.

With the scaled MHDDT ER_{avg} and the EIR derived earlier, the ZMR and DR of NOx and PM for the 2010-12 and 2012+ MY MHDDT were calculated, as shown in Table 4.3-47.

Table 4.3-47. Revised Zero-Mile Rates (g/mi) and Deterioration Rates (g/mi/10K mi) for Diesel Medium Heavy Duty Trucks by Vehicle Model Year†

	HC		CO		NOx		PM		CO_2	
Vehicle MY	ZMR	DR	ZMR	DR	ZMR	DR	ZMR	DR	ZMR	DR
Pre 1987	0.975	0.0555	2.929	0.167	15.61	0.033	0.9897	0.0393	1511	0
1987-90	0.765	0.0660	2.301	0.198	15.39	0.044	1.0752	0.0350	1464	0
1991-93	0.406	0.0345	1.225	0.104	11.51	0.058	0.5908	0.0269	1408	0
1994-97	0.301	0.0397	0.909	0.120	11.30	0.068	0.3359	0.0179	1350	0
1998-02	0.307	0.0394	0.926	0.119	11.12	0.077	0.3676	0.0162	1381	0
2003-06	0.306	0.0286	0.666	0.063	7.64	0.077	0.2526	0.0098	1368	0
2007	0.278	0.0226	0.589	0.048	6.72	0.068	0.1887	0.0073	1404	0
2008	0.204	0.0082	0.454	0.018	4.81	0.041	0.0239	0.0012	1516	0
2009	0.201	0.0077	0.449	0.017	4.74	0.040	0.0176	0.0009	1520	0
2010	0.173	0.0066	0.401	0.015	4.27	0.045	0.0153	0.0008	1512	0
2011	0.045	0.0016	0.181	0.006	2.15	0.067	0.0044	0.0003	1476	0
2012	0.009	0.0003	0.120	0.003	1.55	0.073	0.0014	0.0002	1465	0
2013	0.009	0.0003	0.120	0.003	1.55	0.073	0.0014	0.0002	1455	0
2014	0.009	0.0002	0.120	0.002	1.50	0.067	0.0014	0.0001	1378	0
2015+	0.009	0.0002	0.120	0.002	1.48	0.065	0.0014	0.0001	1359	0

† Emission rates are adjusted for pre-clean diesel fuel. These emission rates are corrected using fuel correction factors.

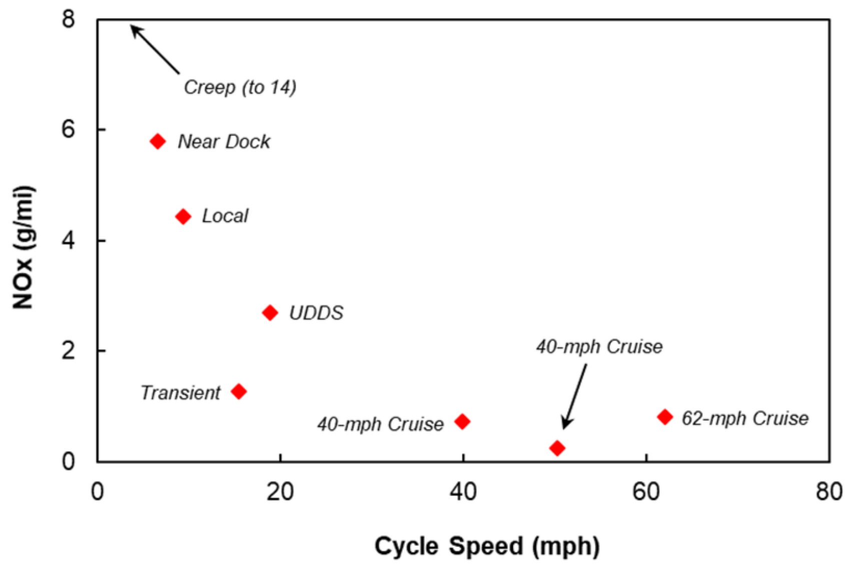
4.3.2.1.4. HDDT SPEED CORRECTION FACTORS (SCF)

EMFAC models truck running exhaust emissions by multiplying emission rates in g/mi by vehicle miles travelled (VMT). VMT are distributed across the whole spectrum of vehicle driving speeds and therefore emission rates at different speeds are needed to match the corresponding VMT. In EMFAC, emission rates at various speeds are calculated from the BER using SCF. An SCF for a pollutant is developed from the pollutant's emission rates measured over a number of test cycles with different average speeds and then normalized to a particular cycle. For HD trucks, test vehicles typically are tested over the UDDS (18.8 mph average speed) and several cycles with an average speed lower and higher than that of the UDDS, and all the emission rates are normalized to the UDDS rate to yield SCFs. Emission rates of a pollutant at various speeds can then be obtained by applying the SCFs to the UDDS based BER of that pollutant.

The SCFs of HC, CO, NO_X, PM, and CO_2 for HD trucks in EMFAC2017 were developed using the emissions test data from test runs over multiple test cycles in the CARB TBSP (see Section 4.3.2.1.1). Test data from multiple test cycles were also collected in the EMA-UCR and CARB MTA testing projects (Appendixes 6.5 and 6.6), but some of the data were not used in developing SCF. As Table 4.3-41 shows, the EMA-UCR and CARB MTA projects used a different set of test cycles from the set used in CARB TBSP. Therefore, the averaged emission rates for those test cycles that are not used in both projects (e.g., 50-mph Cruise) may be greatly affected by the different mix of vehicles tested.

Figure 4.3-57 is a plot of the average NO_X emission rates of all 2013+ MY trucks tested over the 8 test cycles in the three testing projects. The rate for Transient cycle is clearly off the overall trend defined by other data points, and this may also be the case, at least partially, for the 50-mph Cruise cycle. Both the Transient and 50-mph Cruise points are based on the test results of only three trucks from the EMA-UCR/CARB MTA projects, which all had very low mileages (from 3,000 to ~16,000 miles) and yielded NO_X emissions below 1 g/mi during chassis dynamometer testing. In contrast, the data points for Near Dock, Local, and 62-mph Cruise cycles are based on 12 trucks from the CARB TBSP (and 15 trucks from the EMA-UCR project and CARB TBSP for Creep and 40-mph Cruise cycles), with mileages of these trucks ranging from 3,000 to 248,000 miles and NO_X emission rates ranging from below 1 g/mi to close to 10 g/mi. Therefore, in this case an SCF curve fitted from all the cycles would misrepresent the relationship between emission rate and speed. The rate vs. speed charts for HC and CO also show similar patterns, although it is not that notable for CO_2 (likely due to relatively small inter-vehicle variability of CO2 emissions) and cannot be clearly identified for PM (likely due to relatively large inter-vehicle variability of PM emissions as well as the impact of particulate filter regeneration).

Figure 4.3-57: Average NO_X emission rates of 2013+ MY trucks tested over different test cycles. Notice the apparent "low" values of Transient and 40-mph Cruise cycles.



Since in essence SCF is a scaling factor for deriving emission rates at different speeds from the UDDS based BER, staff decided not to use the data from the Transient and 50-mph Cruise in calculating SCFs for all pollutants. Table 4.3-48 shows the average emission rates for the UDDS and the other test cycles.

Table 4.3-48: Average Emission Rates of HHDDT for Different Test Cycles

Test Cycle	HC (g/mi)	CO (g/mi)	NO_X (g/mi)		PM	CO2 (g/mi)
	2010+	2010+	2010 – 2012	2013+	2010+	2010+
Creep	0.274	2.22	15.7	14.0	6.27	6,073
Near Dock	0.064	0.323	8.04	5.79	6.36	2,763
Local	0.046	0.159	7.07	4.43	3.43	2,423
Transient	0.012	0.670	4.05	1.26	8.92	2,360
UDDS	0.018	0.162	4.46	2.69	4.87	2,108
40-mph Cruise	0.008	0.051	1.63	0.73	5.17	1,330
50-mph Cruise	0.099	0.105	0.68	0.25	13.4	1,636
62-mph Cruise	0.012	0.048	2.75	0.81	18.2	1,537

An analysis of the test data shows that as in EMFAC2014, for NO_X one SCF curve can be developed for the 2010-2012 MY group and another for the 2013+ MY group but for HC, CO, PM, and CO_2 one SCF curve should be used for all 2010+ MYs. For HC and CO, the data variation is large and it is appropriate to aggregate all test data and find an SCF that best fit the data. For CO_2, very little difference exists when the data were separated into a 2010-2012 MY group and a 2013+ MY group, and therefore all data were combined together to generate a single SCF curve for all 2010+ MYs that in effect should improve the calculations of CO_2 emissions across the different speeds.

For PM, although all test vehicles were equipped with a DPF, the PM data showed considerable variations among different test vehicles and sometimes even among the different test runs over the same cycle for the same truck. As a result, when the PM data were analyzed separately for the 2010-2012 and 2013+ MY groups, a meaningful emissions-speed relationship could not be found. Combining the data as a single 2010+ model year group resulted in a more reasonable data fit.

For a given MY group, emission rates of a pollutant were first plotted as a function of speed. Regression curves were then fitted to find the equations best representing the data. In finding the best empirical curves that relates the emission rates and speeds, in the case of PM a single regression curve was able to be fitted through all points, whereas in the case of all other pollutants a two-segment curve had to be used to fit the data points.

Based on data fitting, it was decided that for speed below 18.8 mph, Eq. 4.3-10 can be used for calculations of SCFs for all pollutants; and for speed between 18.8 and 65 mph, Eq. 4.3-11 can be used for calculations of SCFs for all pollutants.

$$SCF = \frac{A \cdot speed^B}{A \cdot 18.8^B} \qquad \text{(Eq. 4.3-10)}$$

$$SCF = \frac{C + D \cdot speed + E \cdot speed^2}{C + D \cdot 18.8 + E \cdot 18.8^2} \qquad \text{(Eq. 4.3-11)}$$

In Eqs. 4.3-10 and 11, *A, B, C, D,* and *E* are coefficients for the respective equations, and Table 4.3-49 lists the numeric values of these coefficients for calculating the SCFs of all five pollutants for 2010-2012 and 2013+ MY groups.

Table 4.3-49: Coefficients for EMFAC2017 HHDDT Speed Correction Factors

Pollutant	Model Year Group	5-18.8 mph		18.8-65 mph		
		A	B	C	D	E
HC	2010+	0.553	-1.15	3.77×10^{-2}	-1.33×10^{-3}	1.48×10^{-5}
CO	2010+	3.64	-1.20	0.350	-1.24×10^{-2}	1.19×10^{-4}
NO_X	2010-12	21.7	-0.527	10.2	-3.85	4.28×10^{-3}
	2013+	21.3	-0.702	6.14	-0.225	2.25×10^{-3}
PM	2010+	Same as 18.8-65 mph		7.34	-0.297	7.34×10^{-3}
CO_2	2010+	7,450	-0.469	3,610	99.8	1.07

A comparison between the Revised SCFs and the EMFAC2014 SCFs are graphically shown in Appendix 6.7.

4.3.2.2. IDLE EMISSION RATE

Historically in EMFAC, emissions from extended idling by HD trucks have been modeled using test data collected from dynamometer testing over the Idle Mode of the CARB's 4-Mode Cycle. These tests are generally performed by running a test vehicle's engine at certain idle speed with no accessary loading (e.g., the vehicle's A/C or heater). Such idles are called as "low idles" or "curb idles". During extended idling, truck drivers often idle the engines with A/C or heaters turned on for necessary cooling or heating. These idles with accessary loading are referred to as “high idles” and are used to model truck idle emissions for summer and winter weather conditions. Since dynamometer based idle testing usually does not perform high idle tests, high idle emission rates have been estimated by applying high idle correction factors to the low idle emission rates.

In recent years, there have been efforts to test truck idle emissions using a portable emissions measurement system (PEMS) in the field under the ambient conditions or inside a chamber with controlled temperatures. Because idle emissions usually take 10 to 20 minutes to become stabilized and a PEMS test can run a much longer period of time than a typical idle test on a dynamometer, the idle emission rates determined based on the stabilized emissions are much less affected by the engine starts or pre-test preconditioning. This is particularly important for the NO_X emissions of SCR-equipped trucks as the engine temperature prior to an idle test will have a significant impact on the resulting idle emissions.

For EMFAC2017, emissions data from both chassis dynamometer and PEMS testing were used to update the idle emission rates for HHDTs. The following sections describe the sources of test data sources, the analysis of the collected test data, and the updated truck idle emission rates.

4.3.2.2.1. SOURCES OF EMISSIONS TEST DATA

Test data used for updating HHDT idle emission rates were obtained from several sources, including data from a PEMS testing project carried out by CARB during 2015-16, a dynamometer testing project conducted by CARB in 2015, and a HD truck emissions study performed by the Texas Transportation Institute (TTI) for Texas Department of Transportation in 2014.

CARB PEMS testing project

In this project, emissions were measured for a 60-min engine idle after an overnight soak (cold start idle) and after a run over a prescribed test route (warm start idle). All cold idle tests were performed without A/C or heater on. For the warm start idle tests, the engine was first idled for 15 minutes with no A/C or heater turned on (low idle), then another 15 minutes with A/C on (high idle), then a third 15 minutes with no A/C or heater on, and finally an additional 15 minutes with the heater on (high idle).

Four trucks were tested for their idle emission rates of HC, CO, NO_X, and CO_2. However, in several cold start idle tests, emissions did not reach stabilized levels even after 45-50 minutes. For those cold start runs in which emissions did reach stabilized levels after 30-45 minutes, the stabilized emission rates are similar to the rates for the third 15-min segment (no A/C or heater on) of the corresponding warm start runs, suggesting that the stabilized idle emission rates are not affected by the type of starts. The idle test data from the CARB PEMS testing project are summarized in Appendix 6.8.

TTI idle testing data

As part of a truck emissions study project, TTI tested 15 trucks for their idle emissions. The idle testing was conducted inside a test chamber under controlled conditions, with temperature set at 100 °F for hot tests and at 30 °F for cold tests to simulate summer and winter weather conditions. Detailed description of the test vehicles and testing methodology can be found in the TTI final report[51].

Of the 15 test vehicles tested by TTI, eleven trucks (ranging from 2008 to 2014 model years) were certified to the federal clean idle requirements and eight trucks (all 2010+ model years) were identified as also certified for sales in California. For this update, the test data for the eight California clean idle certified trucks were used, and the results from these test vehicles are listed in Appendix 6.9.

4.3.2.2.2. IDLE EMISSION RATES OF HEAVY-DUTY DIESEL TRUCKS

CARB PEMS testing provided emissions data for both low idle (with no accessary loading) and high idles (with either A/C or heaters on). The ambient temperatures during all idle test runs ranged from 50 °F to 90 °F, covering most weather conditions experienced in California. The TTI project performed low idle tests and only tested trucks with A/C on at 100 °F and with heater on at 30 °F, and these are close to represent the two extreme ends of the weather conditions in California.

The PEMS test data from both the CARB and TTI testing projects were used to update the idle emission rates of HC, CO, NO_X, and CO_2 for 2010+ model year trucks in EMFAC. The CARB dyno test data were not used for updating the idle emission rates of gaseous pollutants because of the impact of the SCR light-off times on the idle emissions levels of these pollutants, as seen in PEMS test results, and also because of the lack of emissions results for high idles. However, the CARB and TTI PEMS testing projects did not provide idle emissions data for PM. As a result, the emissions results obtained from the CARB dynamometer testing were used to estimate the PM idle emission rate. It is likely that the PM idle emissions are much less affected by the engine temperature at the start of a dynamometer idle run than the gaseous pollutants.

The low idle emission rates of HC, CO, NO_X, and CO_2 were calculated directly from the emissions results of the low idle runs of the CARB PEMS testing. For high idle emission rates, the rate for the summer season was obtained by averaging the CARB high idle emissions with A/C loading and the TTI high idle emissions from tests at 100 °F with A/C on, and similarly the rate for the winter season was obtained by averaging the CARB and TTI high idle emissions when the heater was on.

For PM, the emissions results from the dynamometer runs over the Idle Mode were used to calculate the low idle emission rate. The high idle PM emission rate was obtained by multiplying the low idle rate by the high idle correction factors for the summer and winter seasons from EMFAC2014 (EMFAC2014 Technical Documentation[52]). It should be noted that during EMFAC2014 update, most dynamometer test runs over the Idle Mode did not produce reportable values for PM emissions, and therefore a value of 0.001 g/hr was assigned for the PM idle emission rate for 2007+ model years. Since in the current update, there is no test data

---

[51] Texas-specific drive cycles and idle emission rates for using with EPA's MOVES model – Final Report, 2014.

[52] California Air Resources Board, EMFAC2014 Volume III – Technical Documentation, 2015.

for the 2007-2009 model years, the low and high idle emission rates of PM for 2010+ model years were assumed to be also apply to the 2007-09 model years. The truck low idle rates, high idle emission rates for summer, and high idle emission rates for winter are summarized in Table 4.3-50.

Table 4.3-50: Updated Idle Emission Rates for Heavy Heavy-Duty Diesel Trucks of 2007-2009 and 2010+ Model Years (in g/hr)

Idle Mode	Engine MY	HC	CO	NO_X	PM	CO_2
Low	2007-09	1.88	3.71	33.0	0.0041	5,318
	2010+	2.21	35.7	25.3	0.0052	6,012
High (summer)	2007-09	3.20	11.5	69.4	0.017	12,230
	2010+	3.60	32.8	33.8	0.021	7,337
High (winter)	2007-09	4.14	27.1	59.5	0.024	9,572
	2010+	2.65	35.5	42.9	0.029	7,867

4.3.2.3. START EMISSION RATE

Start emission rates of NO_X for HD trucks were developed based on the emissions data collected from CARB Project 2R1406 "In-Use Testing of Heavy-Duty Vehicles Certified to Applicable 2010 Emission Standards". In the project, four 2012-2014 model year trucks with an SCR system were tested at CARB Depot Park facility using PEMS for the emissions of gaseous pollutants.

The start emission tests were treated as normal driving runs to mimic real world driving habits. All start emission test runs were performed on a medium load configuration (i.e., 70 percent of Gross Vehicle Weight Rating) on a route referred as DPTODP, which is an uninterrupted round trip starting from Depot Park and covering a distance of about 15 miles before ending at Depot Park. For each test vehicle, start emission test was conducted following soak times of overnight 720 min, 240 min, 120 min, 90 min, 60 min, 30 min, 15 min, and 5 min.

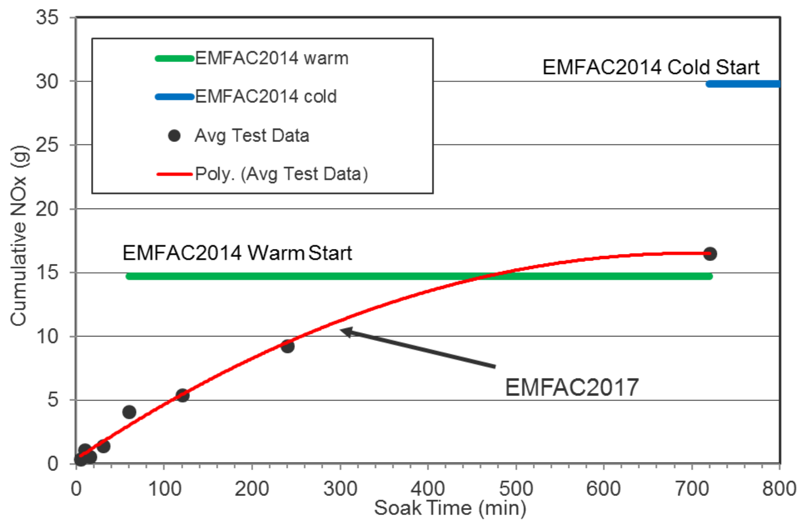
The method for analyzing start emission data is the same as that used for the EMFAC2014 update. Briefly, the NO_X emissions during the start phase are considered to include start emissions and running emissions (which represent emissions that would otherwise be emitted had the SCR reached operating temperatures), so for a test run the start emission rate is obtained by subtracting the NO_X emission rate of the running phase from the emission rate of the start phase and then multiplying it by the duration of the start phase. A detailed discussion about the calculation of start emission rate can be found in Section 3.2.3.6 of EMFAC2014 technical support documentation[53].

The start emission rates for the four HD diesel trucks were calculated for all test runs and the results are provided in Appendix 6.10. In Figure 4.3-58 the calculated NO_X start emission rates

[53] California Air Resources Board, EMFAC2014 Volume III – Technical Documentation, 2015.

are plotted versus the corresponding soaking time. Also shown in the figure are the start emission rates used in EMFAC2014. Unlike in EMFAC2014, for which only a cold start rate and a warm start rate were able to be calculated from the available data, a relationship between the NO_X start emission rate and soaking time was established based on the test data, as represented by the best fit regression curve in the figure. Figure 4.3-58 shows that the NO_X start emission rate for EMFAC2017 is lower than the warm start emission rate for EMFAC2014 when soaking time is less than about 400 minutes but higher for soaking longer than 400 minutes; however, the start emission rate for EMFAC2017 is significantly lower that the cold start emission rate for comparable soaking times.

Figure 4.3-58: NO_X start emission rate as a function of soaking time. Also shown are the warm and cold start emission rates used in EMFAC2014



In EMFAC2014, start emissions were calculated from multiplying the cold and warm start emission rates by the number of daily cold and warm starts, which were calculated from truck activities estimated based the Telematic and PierPass data for HD trucks. For EMFAC2017, start emission rate takes the form of emission rates versus soaking time, and thus data on soaking time for vehicles are needed in order to calculate start emissions. Soaking times for HD trucks of various service types were estimated based on data obtained from a contract study of heavy duty vehicle activities conducted by UCR, and a detailed discussion of the UCR data is presented in Section 4.4.3.

4.3.2.4. RUNNING EXHAUST EMISSION RATES (TRANSIT BUSES)

4.3.2.4.1. SOURCE OF EMISSION TEST DATA

Emission data used for updating transit bus emission rates were obtained from several sources. One set of emissions data were acquired from the Integrated Bus Information System (IBIS) of West Virginia University (WVU). The IBIS is an internet information resource to help transit agencies evaluate the impact of fuel and propulsion technology on emissions of pollutants, fuel efficiency and vehicle life cycle costs. It includes chassis dynamometer testing results of transit buses tested over several common test cycles. From the IBIS emission data were obtained for

29 diesel buses of 1986-2008 model years and 10 CNG buses of 2005-2008 model years. These emissions results are based on the Orange County Transit Bus (OCBC) test cycle.

Another set of emissions data were obtained from a transit bus testing project conducted by CARB for Valley Transit Agency (VTA) in California. It includes two diesel buses of 2011 model year and three CNG buses of 2011 and 2012 model years. The emissions results are based on the OCBC test cycle. In addition, CARB recently also tested two 2008 model year CNG buses on dynamometer over the OCBC cycle as part of laboratory-field testing study of transit buses.

A third set of emissions data came from the Altoona Bus Research and Testing Center sponsored by the Federal Transportation Agency. The Altoona center tests transit buses from manufacturers and provide an unbiased and accurate comparison of bus models using an established set of safety and emissions test procedures. The emissions testing was performed on all buses so that emission levels of different buses can be compared and can be used by transit operators for purchase decisions. The Altoona data includes test results of some of the newest model year buses.

Emission testing data for all tested diesel buses from the above three data sources were compiled into one dataset in Appendix 6.11, and similarly test data for all tested CNG buses were compiled into a second dataset in Appendix 6.12.

The above described datasets do not provide emissions data for pre-2003 model years of CNG buses. As a result, the emission rates for pre-2003 model years CNG buses remain to be based on the dataset compiled from the literature and used in EMFAC2014. The data are based on the Central Business Cycle (CBD), and thus the emissions results were converted into OCBC based by using OCBC/CBD ratios derived from test results of several buses tested over both of these two cycles. For more details, refer to EMFAC2014 Technical Documentation[54].

4.3.2.4.2. EMISSION RATES OF DIESEL AND CNG TRANSIT BUSES

For emission rate calculations, diesel transit buses were grouped into four model year groups: Pre-2003, 2003-2006, 2007-2009, and 2010+ model years. These groups correspond to major changes in NO_X and PM emission standards of bus engines to which manufacturers certified. Table 4.3-51 shows the grouping and the applicable emission standards for each group.

Table 4.3-51: Model Groups for Diesel Buses

Model Year Group	Emission Control	Emission Standard (g/bhp-hr)	
		NO_X	PM
Pre-2003	DOC	4	0.05
2003-2006	DOC/DPF	2.5	0.01
2007-2009	EGR/DPF	1.2/2.5	0.01
2010+	SCR/DPF	0.2	0.01

[54] EMFAC2014 Tech Documentation.

For CNG transit buses, three model year groups were defined in accordance with the reported CNG engine certifications by manufacturers, as shown in Table 4.3-52.

Table 4.3-52: Model Groups for CNG Buses

Model Year Group	Emission Control	Emission Standard (g/bhp-hr)	
		NO_X	PM
Pre-2003	OxCat	1.8-2.5	0.05
2003-2007	OxCat	1.2-1.8	0.01
2008+	TWC	0.2	0.01

For each model year group in Tables 4.3-51 and 4.3-52, the measured emissions of each pollutant for all buses in that group were averaged to obtain an average emission rate. The results for diesel and CNG buses are given in Tables 4.3-53 and Table 4.3-54, respectively. Note that no HC data were reported for any of the 2010+ model year diesel buses; thus, the HC rate for the 2010+ group was derived by multiplying the 2007-2009 HC rate by the ratio of the 2010+ to 2007-2009 CO rates.

Table 4.3-53: Average emission rates of diesel buses by model year group*

Model Year Group	HC (g/mi)	CO (g/mi)	NO_X (g/mi)	PM (g/mi)	CO_2 (g/mi)
Pre-2003	0.393	2.37	27.6	0.319	2,697
2003-2006	0.144	1.68	12.6	0.0126	2,358
2007-2009	0.605	0.968	8.13	0.0126	2,432
2010+	0.119	0.190	1.70	0.0060	2,029

* Emission rates are on the OCBC cycle basis.

Table 4.3-54: Average emission rates of CNG buses by model year group*

Model Year Group	HC (g/mi)	CO (g/mi)	NO_X (g/mi)	PM (g/mi)	CO_2 (g/mi)
Pre-2003	17.1	41.6	20.3	0.0217	2,325
2003-2007	21.0	0.833	17.1	0.0151	2,048
2008+	8.17	58.0	0.61	0.0050	2,237

* Emission rates are on the OCBC cycle basis.

As discussed previously, it is generally believed that transit buses tend to be tampering free and relatively well maintained and properly repaired. Thus, it is assumed that for buses the emissions deterioration is negligible and emission levels measured at high mileages are similar to those at low mileages. As a result, average emission rates in Tables 4.3-53 and 4.3-54 will be used for modeling the emissions of diesel and CNG transit buses with any odometer readings.

4.3.2.4.3. SPEED CORRECTION FACTORS FOR TRANSIT BUS EMISSION RATE

There is no data to determine a relationship between emission rate and speed for diesel buses and non-TWC CNG buses. Therefore, similar to EMFAC2014, the speed correction factors (SCF) developed for heavy-duty diesel trucks (HDDT) are used for transit buses. Table 4.3-55 shows the three HDT model year groups and the corresponding diesel bus model year groups for which the HDT SCFs will be used.

Table 4.3-55: Speed Correction Factors for Diesel Buses

Model Year Group		Speed Correction Curve
Diesel Bus	HD Diesel Truck	
Pre-2003	Pre-2003	SCF for Pre-2003 HDDT
2003-2006	2006-2006	SCF for 2003-2006 HDDT
2007-2009	2007-2009	SCF for 2007-2009 HDDT
2010+	2013+	SCF for 2013+ HDDT

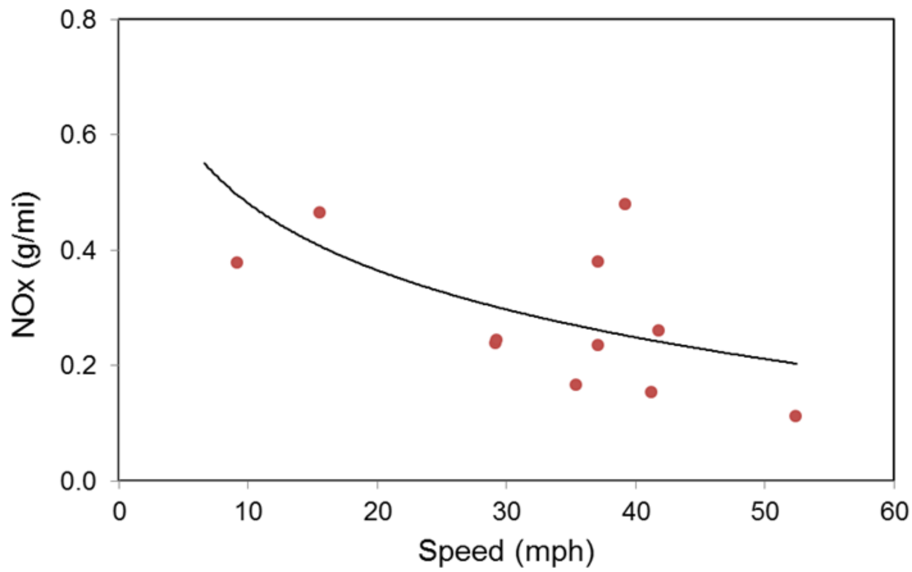
For CNG transit buses, the Pre-2003 and 2003-2007 model year groups are compression ignition engines and generate NO_X emissions not very different from the diesel engines with equivalent emission controls. Thus, for these two groups of buses the SCFs for the Pre-2007 and 2007-2009 model year groups of HDDTs are used, respectively, as shown in Table 4.3-56.

Table 4.3-56: Speed Correction Factors for CNG Buses

Model Year Group		Speed Correction Curve
CNG Bus	HD Diesel Truck	
Pre-2003	2003-06	SCF for 2003-06 HDDT
2003-2007	2007-2009	SCF for 2007-2009 HDDT
2008+	--	SCF based on CNG HDT data

For the 2008+ model year group of CNG buses, the engines are spark ignited with a TWC as the primary control for emissions, and none of the speed curves for HDDTs seems to be suitable for these buses. The Cross-CA PEMS testing project conducted by CARB and WVU tested a CNG powered HD truck on roads in California. From the test data collected by this project, average emissions were obtained for several trips of different average speeds. The data is summarized in Appendix 6.13. Based on this CNG truck testing data, an emission rate vs speed curve was fitted for each pollutant. As an example, Figure 4.3-59 shows the NO_X emission rates at different average speeds and the best fit curve.

Figure 4.3-59: NO_X emission rates at different average trip/cycle speeds. The line is the best fit curve for all data points



From the fitted equation, SCFs were calculated and are used for CNG buses of 2008+ model years. Table 4.3-57 lists the fitted SCF-speed equations for all pollutants for speeds up to 60 mph. For speeds over 60 mph, all SCFs were set to equal the respective values at 60 mph for all pollutants.

Table 4.3-57: Speed Correction Factors for 2008+ Model Year CNG Buses

Pollutant	SCF Equation
THC	-1.031 x ln(speed) + 5.906
CO	-2.076 x ln(speed) + 16.22
NO_X	-0.130 x ln(speed) + 0.727
PM	6.34×10^{-6} x (speed)^2 – 6.16×10^{-4} x (speed) + 1.74×10^{-2}
CO_2	-549 x ln(speed) + 3597

4.3.3. REGULATORY IMPACT

4.3.3.1. FEDERAL HEAVY-DUTY GHG EMISSIONS STANDARDS (PHASE TWO)

In 2013, CARB adopted the California Phase 1 regulations, aligning California's medium- and heavy-duty vehicle and engine regulations with the Federal Phase 1 program, which are reflected in EMFAC2014. In conjunction with the adoption of the California Phase 1 regulations, CARB amended our existing tractor-trailer GHG regulation making it consistent with the federal program. CARB's adoption of Phase 1 gave manufacturers the ability to certify in California and gave CARB the authority to enforce the regulatory requirements.

The Phase 1 rule was designed to get "Off-The-Shelf" GHG emission reduction technologies onto the 2014 through 2018 model year fleet. Phase 1 will reduce CO_2 emissions in California by 12 percent in 2030.

On August 16, 2016, the U.S. EPA and NHTSA released a pre-publication version of the Phase 2 standards. The final version of the Phase 2 rule was published on October 25, 2016. The Phase 2 standards are the second phase of federal heavy–duty GHG standards and build upon the Phase 1 standards. The Phase 2 standards are technology forcing, affordable and flexible. On a national basis, Phase 2 will save over 82 billion gallons of fuel, and cut CO_2 by over 1 billion metric tons to help achieve our climate goals and save vehicle owners $170 million in fuel costs.[55]

4.3.3.1.1. OVERVIEW OF REGULATIONS

The regulation imposes new requirements for newly manufactured compression and spark ignited engines in Class 2b through Class 8 vehicles. Phase 2 requirements begin with model year 2018 for trailers and model year 2021 for engines and vehicles, and phase–in through 2027 model year. The Rule organizes truck compliance into four groupings as shown below. The Federal Phase 2 program includes the first ever CO_2 emission standards for manufacturers of trailers used in combination with tractors. The Phase 2 trailer program begins with trailers manufactured on or after January 1, 2018. The standards get progressively more stringent for 2021, 2024, 2027 and later MY vehicles. CARB is proposing to align California's Phase 2 GHG standards with the federal Phase 2 program. The groupings are:

- Large pickups and vans (Class 2b, 3)
- Vocational vehicles (VV) (Class 4 through 8)
- Combination tractors (Class 7, 8)
- Trailers pulled by combination tractors (introduced in Phase 2)

[55] Item 16-9-3: Update on Phase 2 Greenhouse Gas Emission Standards for Medium- and Heavy-Duty Engines and Vehicles, and Related Research Studies. https://www.arb.ca.gov/board/books/2016/102016/16-9-3pres.pdf

4.3.3.1.2. CO_2 EMISSION RATES

Using these population/VMT shares, staff aggregated the emission rates obtained from the vehicle standards to obtain a composite CO_2 emission rate (g/mile) applicable to each EMFAC2017 vehicle category.

For this analysis, school bus, urban transit bus, motor coaches, motor homes, and all other buses were assigned the same reduction level as medium-heavy duty vocational vehicles. The trailer reductions are the result of implementing the Phase 2 regulation while keeping the CARB heavy-duty tractor-trailer GHG (TTGHG) regulation in place. The basic assumption is that a Phase 2 compliant trailer complies with TTGHG regulation and therefore the TTGHG regulation will not result in any additional benefit after the Phase 2 standards are implemented. The percentage reductions in CO_2 emission rates with respect to 2010 are shown in Tables 4.3-58 through 4.3-60. More details can be found in Appendix F[56] of Proposed California Greenhouse Gas Emissions Standards for Medium- and Heavy-Duty Engines and Vehicles (i.e., CA Phase 2 staff report).

Table 4.3-58: Phase 1 and 2 CO_2 Reduction Percentage (Class 2b – 3)

Model Year	LHDT1/LHDT2 Reductions		Regulation
	Diesel	Gasoline	
2010	100.0%	100.0%	Phase 1
2014	97.7%	98.5%	
2015	97.0%	98.0%	
2016	94.0%	96.0%	
2017	91.0%	94.0%	
2018-2020	85.0%	90.0%	
2021	82.9%	87.8%	Phase 2
2022	80.8%	85.6%	
2023	78.8%	83.4%	
2024	76.8%	81.4%	
2025	74.9%	79.3%	
2026	73.0%	77.3%	
2027+	71.2%	75.4%	

56 https://www.arb.ca.gov/regact/2018/phase2/appf.pdf

Table 4.3-59: Phase 1 and 2 CO_2 Reduction Percentage (T6, T7 and Buses)

Model Year	Composite Reduction T6	Composite Reduction T7	Buses	Regulation
2010	100.0%	100.0%	100.0%	Phase 1
2014	94.7%	87.0%	94.7%	
2015	94.7%	87.0%	94.7%	
2016	94.7%	87.0%	94.7%	
2017	91.1%	84.5%	91.1%	
2018-2020	91.1%	84.5%	91.1%	
2021-2023	82.4%	74.2%	82.4%	Phase 2
2024-2026	76.2%	68.6%	76.2%	
2027+	73.4%	65.5%	73.4%	

Table 4.3-60: Phase 2 and TTGHG CO_2 Reduction Percentage (Trailers)

Trailer Type	Assumed Distribution from MOVES	Reductions			
		2018-2020	2021-2023	2024-2026	2027+
53'+ Dry Van	55.50%	6.7%	9.0%	10.5%	11.8%
<53' Dry Van	12.30%	2.9%	4.2%	5.1%	5.6%
53'+ Reefer	18.20%	5.8%	8.3%	10.0%	11.6%
<53' Reefer	5.20%	2.7%	3.8%	5.2%	5.9%
Container Chassis	0.20%	2.0%	3.0%	3.0%	3.0%
Flatbed	6.90%	2.0%	3.0%	3.0%	3.0%
Tank	0.40%	2.0%	3.0%	3.0%	3.0%
Other On-Highway	1.20%	0.0%	0.0%	0.0%	0.0%
Other Off-Highway	0.00%	0.0%	0.0%	0.0%	0.0%
Weighted Average	Combination Tractor-Trailer (except drayage trucks)	5%	7%	9%	10%
	Drayage trucks pulling container chassis only	2%	3%	3%	3%

4.3.3.2. LEV 3 PM EMISSION STANDARDS – EMISSION RATES UPDATE

The EMFAC2014 model used a fleet average PM emission rate (ER) that varies by model year (MY) to compute the PM emissions of passenger cars, light duty passenger trucks (<8500 lbs GVWR), and medium duty passenger vehicles.[57,58] The EMFAC2014 fleet average PM ER was constructed assuming that each vehicle could be assigned to one of four PM emission groups, defined by fuel-injection type, and PM certification standard.

(1) Port Fuel Injection Vehicles (PFIs): Composite FTP PM ER = 0.5 mg/mi
(2) Pre-LEV 3 Gasoline Direct Injection Vehicles (GDIs): Composite FTP PM ER = 4 mg/mi

[57] EMFAC2014 Technical Documentation pg 44-46
[58] ARB 2011a, LEV III ISOR, http://www.arb.ca.gov/regact/2012/LEV 3ghg2012/levisor.pdf

(3) LEV 3 3 mg/mi Certified GDIs: Composite FTP PM ER = 3 mg/mi
(4) LEV 3 1 mg/mi Certified GDIs: Composite FTP PM ER = 1 mg/mi

The LEV 3 regulations were incorporated into EMFAC2014 using reduction factors (RF), which corrected for the change in the fleet fractions of the four types of PM emitters as a result of the LEV 3 phase-in (Table 4.3-61) using an assumed compliance path (Table 4.3-62).

Table 4.3-61: The phase-in schedule of the LEV 3 PM standards.

	Fraction of Vehicles Certified to:	
MY	3 mg/mi Standard	1 mg/mi Standard
2017	10%	0%
2018	20%	0%
2019	40%	0%
2020	70%	0%
2021	100%	0%
2022	100%	0%
2023	100%	0%
2024	100%	0%
2025	75%	25%
2026	50%	50%
2027	25%	75%
2028+	0%	100%

Table 4.3-63 displays the EMFAC2014 fleet composite FTP PM ERs for the baseline scenario (no LEV 3) and the LEV 3 scenario. In EMFAC2014, the baseline scenario ERs were adjusted to the LEV 3 scenario ERs using the reduction factors (RFs) shown in the table. Note that the baseline scenario assumed that there were only two vehicle types: 4mg/mi GDIs and 0.5 mg/mi PFIs. Both scenarios assume that the percentage of GDIs increase to 70 percent by 2021 (due to improved fuel efficiency), and the percentage of PFIs shrink to 30 percent.

Table 4.3-62. Assumed Compliance Path for LEV 3 Particulate Emission Standard Scenario

	Fraction of PM Emission Group Vehicles Sold			
MY	PFI	Pre-LEV 3 GDI	LEV 3 3 mg/mi Certified GDI	LEV 3 1 mg/mi Certified GDI
2016	40%	60%	0%	0%
2017	35%	65%	0%	0%
2018	32%	68%	0%	0%
2019	30%	60%	10%	0%
2020	30%	30%	40%	0%
2021	30%	0%	70%	0%
2022	30%	0%	70%	0%
2023	30%	0%	70%	0%
2024	30%	0%	70%	0%
2025	30%	0%	70%	0%
2026	30%	0%	50%	20%
2027	30%	0%	25%	45%
2028+	30%	0%	0%	70%

Table 4.3-63. EMFAC2014 LEV 3 RFs and Baseline and EMFAC2014 Fleet Average FTP PM ERs

MY	Baseline Fleet FTP ER (mg/mi)	EMFAC2014 ACC Reduction Factors	EMFAC2014 Fleet FTP ER (mg/mi)
2007	0.5	*No Reduction Required*	0.5
2008	0.5		0.5
2009	0.6		0.6
2010	0.6		0.6
2011	0.8		0.8
2012	1.0		1.0
2013	1.4		1.4
2014	1.9		1.9
2015	2.3		2.3
2016	2.6		2.6
2017	2.8		2.8
2018	2.9		2.9
2019	3.0	0.97	2.9
2020	3.0	0.86	2.6
2021	3.0	0.76	2.3
2022	3.0	0.76	2.3
2023	3.0	0.76	2.3
2024	3.0	0.76	2.3
2025	3.0	0.76	2.3
2026	3.0	0.63	1.9
2027	3.0	0.46	1.4
2028+	3.0	0.29	0.9

Although the RFs were developed using data from the FTP driving cycle, EMFAC uses the Unified Cycle phases 1 and 2 (UC_{P1} and UC_{P2}) to estimate vehicular emissions. EMFAC's UC1 and UC2 PM emission factors were adjusted using the RFs above according to the equation below.

$$\text{LEV 3 } UC_{Pi,MY} = \text{Baseline } UC_{Pi,MY} * RF_{MY} \quad \text{(Eq. 4.3-12)}$$

Changes to the GDI Emission Rates in EMFAC2017

New composite FTP ERs for LEV 3 Certified GDIs have been incorporated into EMFAC2017. GDI vehicles certifying to the 3 mg/mi standard will now be assumed to emit PM at 1.5 mg/mi, replacing the 3 mg/mi assumption. GDI vehicles certifying to the 1 mg/mi standard will now be assumed to emit at 0.7 mg/mi instead of 1 mg/mi. The justification for changes in these assumptions are presented below.

Updates to estimated particulate matter (PM) emission rates for future vehicles.

Given the 3 mg/mi standard is just starting to phase in now (2017 MY) and the 1 mg/mi standard doesn't begin phase-in until 2025 MY, emission rates for these future vehicles are estimated based on assumptions, including limited testing of the newest vehicles and engineering expertise gained from knowledge and experience. Historical test data for PM and other criteria pollutants, engineering knowledge of PM emission control and future standards, and input from suppliers and vehicle manufacturers provides much of the basis for the estimated future vehicle emission rates.

CARB recently conducted PM tests on a sample of current vehicles utilizing advanced vehicle technologies such as GDI that are expected to be used on most vehicles in the 2018 to 2025 MY timeframe. While none of the tested vehicles were certified to the upcoming 3 mg/mi standard, they generally represented recently designed or revised models that will be required to comply with the 3 mg/mi standard in the very near future. Accordingly, it is assumed that many of the vehicles had initial design and calibration effort applied to them to protect for imminent compliance with the standard. Based on the recent PM emission testing[59] conducted at CARB, in many cases the target emission rate for vehicles likely designed to comply with the 3 mg/mi FTP standard is less than 50 percent of the standard.

This is also consistent with manufacturer's statements (and past practice) that certification levels for newly controlled pollutants have to be considerably below the standards until the manufacturer becomes comfortable with the control technology, testing, and durability. Given enough time and experience with the 3 mg/mi standard, manufacturers could, at least theoretically, optimize their design and calibration process to ensure compliance with minimum headroom and eliminate unnecessary over compliance. However, given that the 1 mg/mi standard will begin phasing in for 2025 MY, it is not expected that manufacturers will have the time nor the resources to optimize at the 3 mg/mi standard before they need to begin designing for the lower 1 mg/mi standard. Accordingly, FTP composite emission rates for future GDI vehicles certifying to the 3 mg/mi standard are conservatively estimated to be 1.5 mg/mi.

For estimating the emission rate for future vehicles certifying to the 1 mg/mi standard, manufacturers would be expected to continue to certify at a level below the actual standard, the stringency of the 1 mg/mi standard is such that it is unlikely that GDI vehicles will be able to certify at 50 percent or less of the standard. This is historically consistent with other criteria pollutants (primarily hydrocarbons and oxides of nitrogen) where relative headroom has decreased as the standards are reduced to very low levels, such as the super ultra-low emission vehicle (SULEV) standards. Manufacturers are expected to use the development time from now until 2025 to gain experience with PM control and better understand durability, which will lead to optimized PM control for the standard. CARB also extensively studied measurement variation at very low PM levels and found measurement variation could be as much as 0.1 or 0.2 mg/mi. Combining these factors, a nominal emission rate of 0.7 mg/mi was selected as appropriate for future vehicles certifying to the 1 mg/mi standard.

Impact of New GDI Emission Rates on Fleet Average Emission Rates and Reduction Factors

For EMFAC2017, the RFs used to derive the UC_{P1} and UC_{P2} PM2.5 emission rates will incorporate the assumption that GDI vehicles, certifying to the 3 mg/mi and 1 mg/mi LEV 3 standards, will have a composite FTP ERs of 1.5 mg/mi and 0.7 mg/mi, respectively. These assumptions will replace the EMFAC2014 assumption that the GDI vehicles will emit exactly at the levels of the standards. These new fleet average ERs and RFs are shown in Table 4.3-64.

[59] https://www.arb.ca.gov/msprog/acc/mtr/appendix_k.pdf

Note that Pre-LEV 3 GDIs are still assumed to have an FTP composite ER of 4 mg/mi, and PFIs are still assumed to have an ER of 0.5 mg/mi.

Table 4.3-64. EMFAC2017 LEV 3 RFs and Baseline and EMFAC2017 Fleet Average FTP PM ERs

MY	Baseline Fleet FTP ER (mg/mi)	EMFAC2017 ACC + New EFs Reduction Factors	EMFAC2017 Fleet FTP ER (mg/mi)
2007	0.5	*No Reduction Required*	0.5
2008	0.5		0.5
2009	0.6		0.6
2010	0.6		0.6
2011	0.8		0.8
2012	1.0		1.0
2013	1.4		1.4
2014	1.9		1.9
2015	2.3		2.3
2016	2.6		2.6
2017	2.8		2.8
2018	2.9		2.9
2019	3.0	0.92	2.7
2020	3.0	0.66	2.0
2021	3.0	0.41	1.2
2022	3.0	0.41	1.2
2023	3.0	0.41	1.2
2024	3.0	0.41	1.2
2025	3.0	0.41	1.2
2026	3.0	0.35	1.0
2027	3.0	0.28	0.8
2028+	3.0	0.22	0.6

4.4. ACTIVITY PROFILES

Activity profile refers to the collection of vehicle activity characteristics that influence vehicle emissions, including speed profile, starts per day, soak time distribution, VMT hourly distribution, start hourly distribution, engine on time distribution and annual mileage accrual rate. EMFAC model developed default activity profiles for light-duty vehicles (LDVs) and HDs to support emission inventory estimation. EMFAC2017 implemented major updates on activity profile for both LDVs and HDs using the latest second-by-second vehicle data collected in recent studies. However, for conformity and State Implementation Plan purpose, user may use local activity profiles developed by transportation planning agencies and run the EMFAC model in the Custom Activity Emissions Mode to develop regional emission inventories for planning.

4.4.1. UPDATES TO LDV ACTIVITY PROFILES

This section discusses the updates on LDV weekday activity profiles and accrual rates. The updates on LDV weekday activity profiles include number of starts per day, start distribution by hour, soak time distribution and engine run time distribution. In previous versions of EMFAC model, the LDV activity profiles were generated based on California statewide travel surveys and instrumented vehicle data collected for the U.S. EPA in Baltimore, Maryland; Spokane, Washington; and Atlanta, Georgia[60]. These data were collected in the last century, and included large fraction of samples from out of California. To ensure that EMFAC model realistically reflects driving patterns in California, the data from 2010-2012 California Household Travel Survey (CHTS) were analyzed to update LDV activities in EMFAC2017. The CHTS is conducted by the California Department of Transportation (Caltrans) every ten years to obtain detailed information about statewide household socioeconomic characteristics and household travel behavior. It is designed to collect data from entire State of California to support regional and statewide travel and environmental models. Multiple agencies, including the California Air Resources Board, joined the Steering Committee that oversaw the survey design and implementation.

In addition to weekday activity profile, EMFAC2017 also presents updates to LDV mileage accrual rates based on a thorough analysis of the latest Smog Check data from BAR. As a result of these updates, mileage accrual rates for light duty vehicles subject to CA Smog Check program were updated.

The default LDV regional speed distributions in EMFAC2017 remains the same as those of EMFAC2014, which is developed from data submitted from MPOs or historical data for areas not covered by MPOs.

4.4.1.1. 2010-2012 CHTS DATA

The 2010-2012 CHTS collected data from over 42 thousand of households between January 2012 and January 2013. Using an address based sampling frame and stratified random

[60] EMFAC2000 Technical Support Documentation, Section 7.6 Light-Duty Automobile Weekday Activity. Available at https://www.arb.ca.gov/msei/onroad/doctable_test.htm

sampling method, the survey sampling plan was designed to ensure an accurate representation of the entire households residing in the 58 counties of the State. The study employed geographic and socioeconomic stratification scheme to ensure geographic and demographic representation. It also used oversampling strategy to ensure coverage of hard-to-reach households[61]. To correctly reflect each sample unit's significance, weighting factors for each sample were calculated and provided in the final data.

The 2010-2012 CHTS used a combination of data collection methods, including Computer Assisted Telephone Interviewing (CATI), online entry, mail surveys, wearable and in-vehicle GPS as well as On-Board Diagnostic (OBD) sensors that read data directly from a vehicle's engine. The survey required all participating households to record a 24-hour travel diary, and to report long distance travel in the prior eight weeks. The GPS/OBD portion of the study included three types of instrumentation: wearable GPS only, in-vehicle GPS, and both in-vehicle GPS and OBD. The wearable GPS data were collected for three days, while the in-vehicle GPS and OBD device data were collected for seven days.

For the purpose of EMFAC update, the in-vehicle GPS and OBD data were used as the primary source to create number of the starts, soak time distribution, and engine run time distribution. The GPS and OBD devices provide more accurate vehicle activity data than the traditional travel diary, as the latter tends to under-report short trips and loop trips. These data included 1,440 household with both in-vehicle GPS devices and 422 households with in-vehicle GPS device only. Each household was provided with a maximum of three GPS or OBD devices to instrument their vehicles. In total, trip data are available from 2,715 vehicles with both GPS and OBD, and from 776 vehicles with GPS only.

The GPS equipment recorded date, time, latitude, longitude, and speed at one-second frequency. The OBD device was configured to collect speed at one second frequency, and air flow rate, throttle position, engine load, and engine speed at six-second frequency. Additional data elements from OBD were reported on a trip basis, including trip start and trip end, trip duration, etc. We primarily used the OBD data to generate light duty vehicle activity profiles and only used GPS data for comparison and quality check. This is because the OBD data records the actual engine start, while the GPS data use time lag such as 120 seconds or more at the same location to define a new trip. Although extra steps were taken to improve the GPS trip designation, including visual reviews to screen out false stops such as traffic delays, or to add extra stops deemed reasonable, the results were still not a direct measurement on engine activity.

Because vehicles included in CHTS study were mostly household vehicles, activity profiles generated from the GPS and OBD data were applied to the following categories only: passenger cars, light-duty trucks and medium duty trucks.

---

[61] California Department of Transportation. 2010-2012 California Household Travel Survey Final Report. June2013. Available at
http://www.dot.ca.gov/hq/tpp/offices/omsp/statewide_travel_analysis/Files/CHTS_Final_Report_June_2013.pdf

4.4.1.2. LDV STARTS PER DAY

Both OBD and GPS data offer number of trips in a particular day made by a household vehicle. However, the trips recorded by OBD device does not always match those generated from GPS device, or those reported by travel diary during the first day. The following GPS/OBD data components were analyzed separately, so that results can be compared:

- OBD data from the vehicles instrumented with GPS and OBD device
- GPS data from the vehicles instrumented with GPS and OBD device
- GPS data from the vehicles instrumented with in-vehicle GPS only

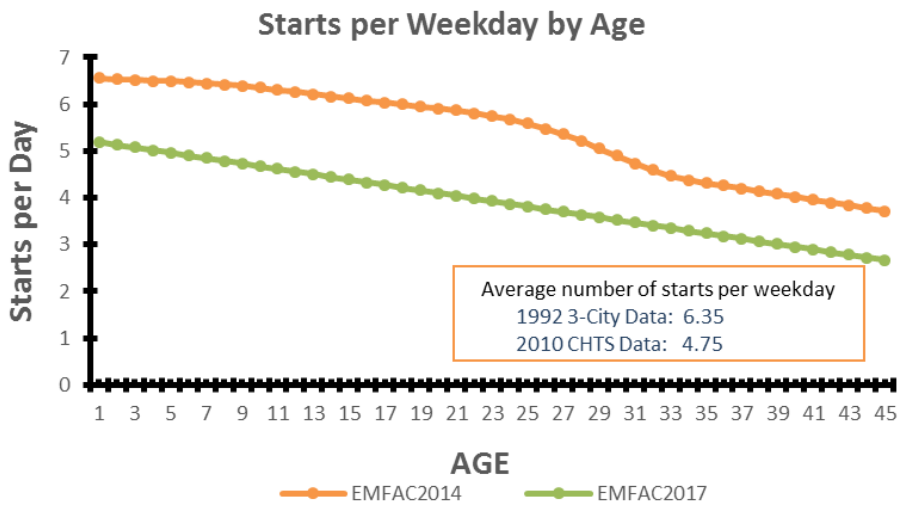
Because EMFAC estimate emissions for a typical weekday, the average number of trips per weekday was computed using weekday data only. For OBD data, we also excluded the CEC add-on samples of 540 households, given that the CEC sampling frame was geared toward alternative and renewable fueled vehicles. Vehicles that made no trip during the seven days were also included to ensure representativeness of infrequently used vehicles. The age of the vehicle is computed as the difference of recruitment year and model year.

The relations between number of starts per weekday and other variables including vehicle age, region, vehicle type and fuel type were investigated using weighted linear regression. The statistical analysis suggested that the average number of starts per weekday was related with vehicle age and to a less degree, vehicle body type, while the effect of fuel type or region on starts per weekday was not statistically supported. Therefore, statewide average starts per week was estimated as a function of age as below:

$$\text{Starts per Weekday} = 5.19 - 0.05729 * \text{Age} \qquad \text{(Eq. 4.4-1)}$$

Where the age is the difference between calendar year and vehicle model year. Under the new starts per weekday assumption, a brand-new light duty vehicle makes 5.2 starts per weekday. As the vehicle ages, the number of starts per weekday reduces linearly to 2.7 at age 45. As shown in Figure 4.4-1, the new assumptions are significantly lower than previous EMFAC assumptions, by a margin ranging from 20 to 30 percent depending on age.

Figure 4.4-1. EMFAC2017 vs. EMFAC2014 number of starts per day



Comparative analysis was performed using the GPS data from the GPS/OBD samples and the GPS data from the in-vehicle GPS only samples. The results are presented in Table 4.4-1. EMFAC adopted the statistics from OBD data considering the accuracy of OBD device in logging engine-on and off events.

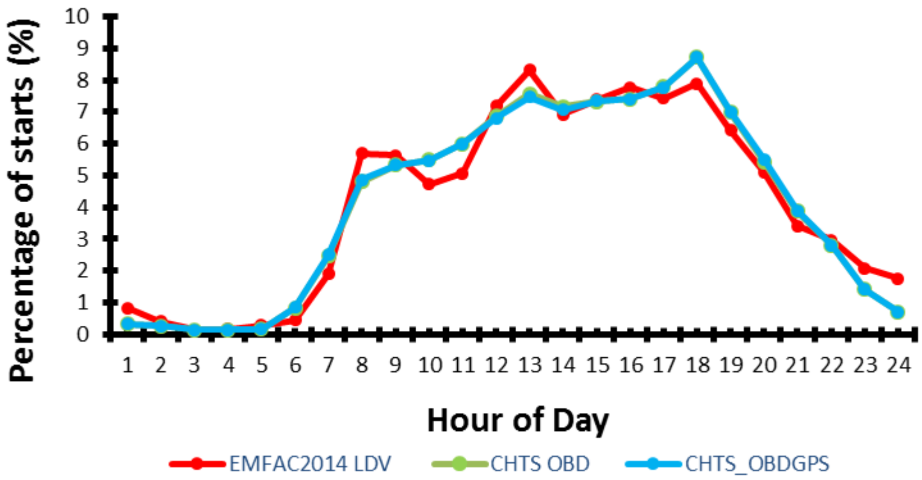
Table 4.4-1: Weighted Average Number of Starts per Day

Data Source	7-day average	Weekday only
GPS from GPS-only samples	5.16	5.18
GPS from GPS/OBD samples	5.15	5.18
OBD from GPS/OBD core samples	4.68	4.75
OBD from GPS/OBD CEC samples	4.56	4.59

4.4.1.3. LDV STARTS DISTRIBUTION

The OBD/GPS data were also used to generate hourly start distribution. Similar to starts per day, data used in this analysis excluded CEC samples, and were properly weighted using household weight factors. Figure 4.4-2 illustrate the distribution of engine starts on a typical weekday. Both OBD and GPS data yields very consistent results. Compared to previous assumption which follows a tri-modal distribution, the mid-day peak is less pronounced and evening peak is more discernible in the new assumption. The fraction of starts by hour of the day is provided in Appendix 6.14.

Figure 4.4-2. EMFAC2017 vs. CHTS Starts Temporal Distribution

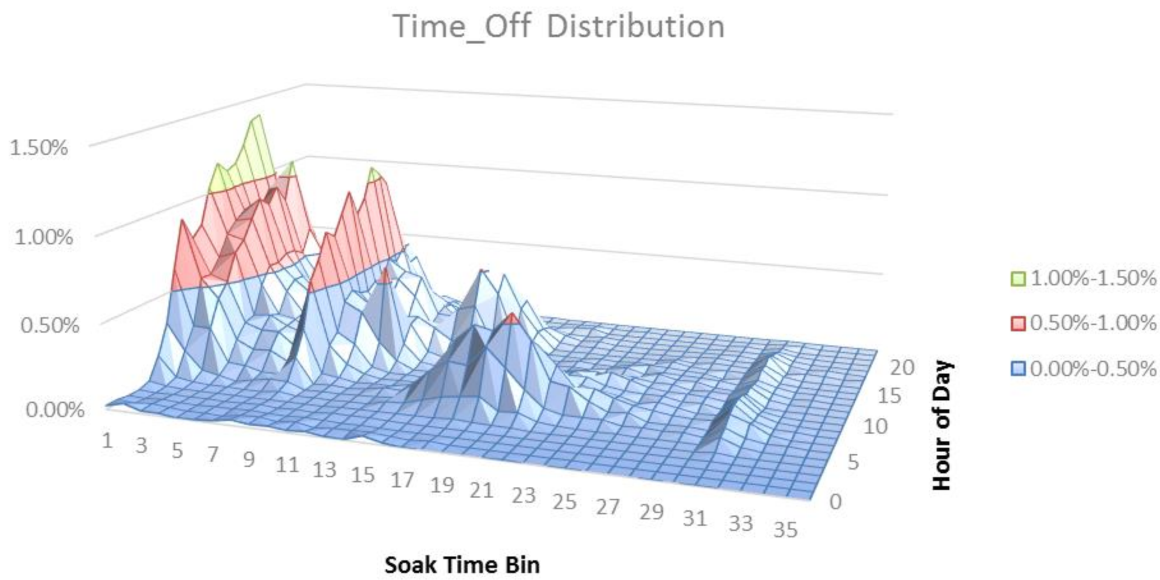


4.4.1.4. SOAK TIME DISTRIBUTION (TIME-OFF DISTRIBUTION)

The soak time distribution is referred to as time-off distribution in EMFAC. Time-off is the length of time the vehicle's engine is off (or soaking) prior to an engine start. It is an important factor in estimating vehicle start emissions. The time-off event is applied to the hour that the start occurred. For example, if a vehicle ended a trip at 5 pm and was restarted at 7 am the next day, this 14-hour time-off event is counted as one of the 7:00 am start activity. Therefore, time-off distribution is a two-dimensional matrix, where activity is classified by hour of the day and soak time bins. The fractions of all 24 hours and all soak time bins sum up to 1.

To ensure accuracy, only complete OBD data is used to create the time-off distribution as OBD records the engine activity. First, trips are connected in sequence, and the soaking time is computed as the difference in time between the prior trip end and next trip start. Then the soak time is classified into bins from 5 minutes to 4 days and above. Next, time-off events are tallied by hour and soak time bin, and the fraction of activity in each hour and bin is computed and weighted by the household sample weights. The time-off distribution is presented in Figure 4.4-3 and fractions are provided in Appendix 6.14.

Figure 4.4-3. EMFAC2017 time off distribution as a function of soak time and hour of the day



4.4.1.5. UPDATE TO LD MILEAGE ACCRUAL RATES

The mileage accrual rate is an estimate of the miles per year traveled per vehicle. Bureau of Automotive Repair (BAR) Smog Check Data were used to derive regional mileage accrual rates by vehicle age and class for LD vehicles using similar methods that have been employed since EMFAC2007. However, as discussed below, some improvements have been made to address inflated accrual rates at early vehicle ages for which limited smog check data exists. As only gasoline powered vehicles were included in the Smog Check program data, it was assumed that diesel vehicles would have the same mileage accrual rates as gasoline powered vehicles of the same class. Additionally, confidential data received from vehicle manufacturers was used to develop new statewide electric vehicle accrual rates. Details of the electric vehicle mileage accrual rates can be found in Appendix G[62] of Midterm Review of Advanced Clean Cars. The following table lists the applicable vehicle classes included in the BAR Smog Check data set used for this analysis.

[62] https://www.arb.ca.gov/msprog/acc/mtr/appendix_g.pdf

Table 4.4-2: Smog Check Vehicle Classes

Vehicle Class (also referred to as)	Weight Class
Passenger Cars (LDA or PC)	All
Light-Duty Trucks (LDT1 or T1)	GVWR < 6000 lbs. and ETW <= 3750 lbs.
Light-Duty Trucks (LDT2 or T2)	GVWR < 6000 lbs. and ETW 3751-5750 lbs.
Medium-Duty Trucks (MDV or T3)	GVWR 6000-8500 lbs.
Light-Heavy Duty Trucks (LHD1 or T4)	GVWR 8501-10,000 lbs.
Light-Heavy Duty Trucks (LHD2 or T5)	GVWR 10,001-14,000 lbs.
Motor Homes (MH)	All
GVWR = Gross Vehicle Weight Rating; ETW = Equivalent Test Weight	

Historical BAR smog check data for the calendar years (CYs) of 2001 through 2014 were available for use in this analysis to develop updated mileage accrual rates. Over 38 million vehicles had records that were matched across biennial review years (such as 2001 with 2003, 2002 with 2004, etc., up to 2012 with 2014.). The earlier year's first record was matched to the later year's first record. An individual vehicle could have up to 12 pairs of these biennial review records, though less would be possible for newer model years. For each matched pair of records, the difference in odometer and difference in test dates were computed. To avoid errors due to odometer readings in vehicles with five-digit displays, only the positive mileage differences were used for this analysis. Based on the differences in dates and odometer readings between biennial review tests, the miles per day were computed. The computed miles per day were transformed into annual miles of accrual based on 365 days/year. To eliminate potential data entry errors, outliers above 200,000 annual miles were also eliminated based on the National Highway Administration National Household Travel Survey methodology[63].

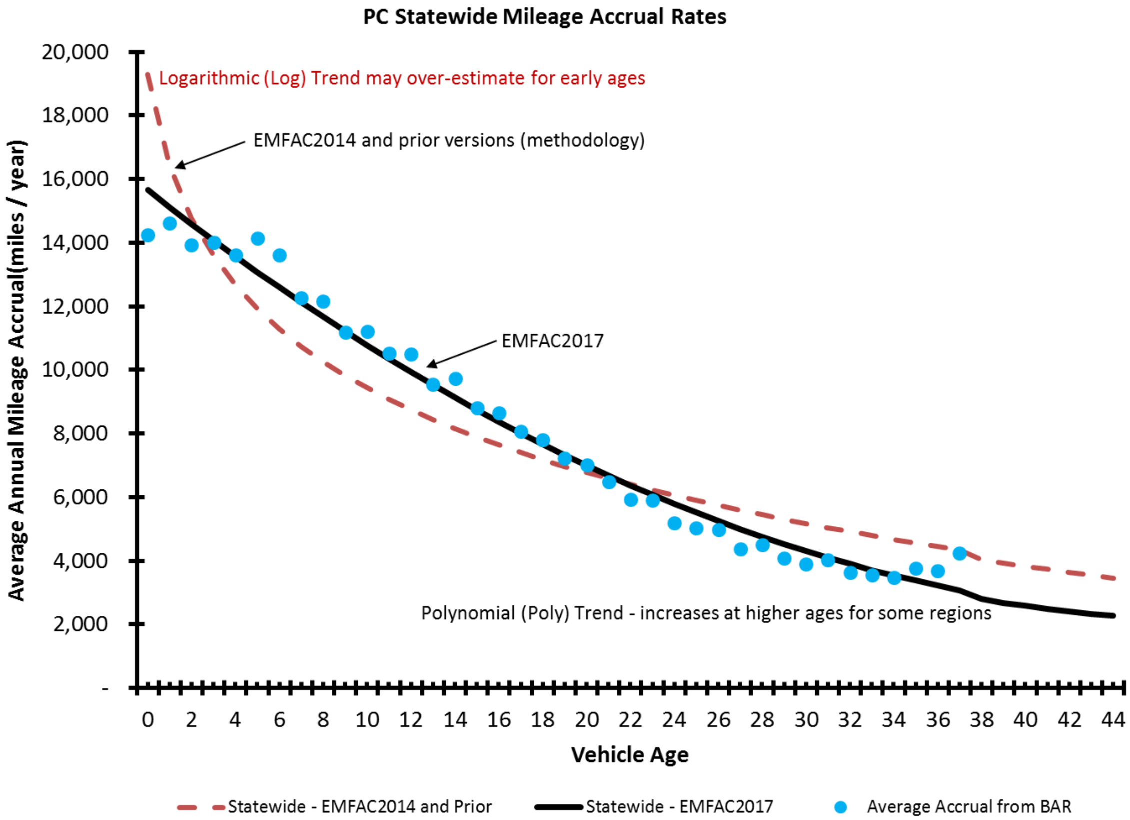
For each region and vehicle class, the average mileage accrual by age was computed which were used to develop regression equations. For prior EMFAC version accrual rate updates, logarithmic regression equations were used. However, this created very high accrual rates at early vehicle ages for which there is limited smog check data available. For ages of one year to five years, the data points available for determining the average mileage accrual by age were limited due to smog check exemptions and no other data sources were available per Sub-Area for comparison purposes. Comments were received questioning these results in EMFAC2014 leading to further investigation for this EMFAC2017 update which determined that non-logarithmic regression equations provide better results. Thus, the EMFAC2017 accrual rates will show some differences from prior EMFAC versions, particularly for the early vehicle ages.

The following figure (Figure 4.4-4) using statewide passenger car accrual data illustrates the different results that can occur from various regression trend options. The x-axis shows the vehicle age and the left y-axis shows the average annual accrual for plotting the accrual per age trend curves. The right y-axis shows the vehicle VIN counts which are displayed in the dotted

[63] National Highway Administration National Household Travel Survey methodology (200k is approx. 550 miles per day), refer to footnote 11 at http://nhts.ornl.gov/2009/pub/BESTMILE.pdf

line. In prior EMFAC updates, the logarithmic curve was utilized but as can be seen in the dashed line, the accrual rates at these low ages are extremely high compared to the raw data and the very low vehicle counts at these early ages are shown in the dotted line. As no other data was available to supplement the BAR data for these low ages, these results indicated that the non-logarithmic trends provided more reasonable results. For most regions, the polynomial curves provided the best fit. However, for some regions the accrual increased at high ages for which corrections using the exponential regressions were utilized.

Figure 4.4-4: Analysis of Accrual Rate Regression Trends



Where it was possible, updated regression equations for mileage accrual were determined by individual Sub-Areas (GAI's). If insufficient data were available to compute mileage accrual rates by individual Sub-Areas, similar Sub-Areas were grouped together as a Region. For LHD1, LHD2, and Motor Homes, there were only sufficient data for establishing statewide average mileage accrual rates. In addition, where insufficient data were available to compute mileage accrual rates for individual vehicle classes, some classes were combined into a single grouping (such as LDT1 and LDT2, LHD1 and LHD2).

For electric vehicles, confidential data provided by vehicle manufacturers was analyzed to assess an average annual mileage. Based on the data provided, the average annual accrual rate trend selected for the base year (CY2015) is 70 percent of the statewide average annual mileage by vehicle age. As battery range will be increasing over time, the 70 percent used for the base year will need to be increased each year to achieve an anticipated 100 percent by CY2025.

Table 4.4-3 summarizes the level of data used to compute the mileage accrual rates, which reside in the default “accrual rate” MySQL table in EMFAC2017. Mileage accrual rates are used to spatially allocate statewide vehicle miles travelled (VMT) as discussed in the VMT methodology section.

Table 4.4-3. Mileage Accrual Rate Documentation

Description	Grouping
LDA = Passenger Cars LDT1 = Light-Duty Trucks (GVWR < 6000 lbs. and ETW <= 3750 lbs) LDT2 = Light-Duty Trucks (GVWR < 6000 lbs. and ETW 3751-5750 lbs) MDV = Medium-Duty Trucks (GVWR 6000-8500 lbs.)	Sub-Area (GAI) or Regional (groups of similar GAIs); Statewide for Electric Vehicles
LHD1 & LHD2 = Light-Heavy Duty Trucks (GVWR 8501-14000 lbs.) MH = Motor Homes	Statewide

Note – Comparing the regional accrual rates to the statewide odometer schedule will show significant variation as the data is derived differently. BAR Smog Check gas-fueled vehicle data is used to derive the statewide average odometer values used for deterioration computations. These statewide odometer averages represent an estimated mid-point of the odometer readings for each model year per calendar year (CY), independent of how long a vehicle has actually been operational. For EMFAC purposes, vehicle age is simply the calendar year minus the model year, and not the true operational age. Vehicles of a given model year could be sold in the prior calendar year as well as across different months for the same calendar/model year. The BAR Smog Check odometer readings for a given model year in each calendar year show wide variability, but tend to display a normal distribution curve and the average odometer value reflects the peak of this curve. Comparing across these peak averages across CYs does not take into account the variability of the actual operational vehicle ages.

The same BAR Smog Check data is also used to derive regional accrual rates, however, paired vehicle data over time is used to compute distance traveled over time, which is then converted to miles per year accrual rates per region of the state (based on the CY of the most current date per pair to determine the vehicle age). As newer model year vehicles are exempt from biennial review, the smog check data collected for accrual purposes is limited, however, no better data source has been identified. It is possible the Smog Check data might be biased and not as representative of the statewide fleet as is desired (such as if it includes more rental vehicles with higher mileage values) but without other data sets for verification purposes, this cannot be determined. The accrual rates are averaged per vehicle age to develop regional accrual curve models. These models provide the average annual miles travelled per vehicle age by regions. These regional values may vary significantly from the average statewide odometer schedule data differences across CYs.

4.4.2. UPDATES TO HDV ACTIVITY

Similar to light duty vehicles, heavy duty vehicle's activity profiles have significant effects on the emissions produced from these vehicles. Recent studies showed that NOx emission rates of newer trucks equipped with SCR technology are much higher at low speeds, during engine start and while idling, as the exhaust temperature needs be high enough (above 250 degree C) for SCR to be fully functional. Therefore, accurate characterization of HD vehicle activity is critical to nowadays HDV emission inventory construction.

Since heavy duty activity data collected at large scale and at fine temporal resolution was very limited, many assumptions in the previous EMFAC models were based on limited or outdated data. For instance, previously EMFAC assumed decades-old statewide HD speed distributions for most regions other than SCAG area, where SCAG provided updated speed distribution from its own commercial truck model. Number of trips per day and hourly trip distribution were based on Battelle and JFA study conducted in the 1990's[64]. Idle assumptions followed methodology used in EMFAC2002[65] and was updated in EMFAC2011 with limited data in an effort to support truck and bus regulation. In addition, HDVs activity profile is high dependent on vocation type, while most of the earlier assumptions only differentiate HD activity by vehicle weight classes, namely, heavy-heavy duty and medium-heavy duty trucks. Such classification is insufficient to capture the diverse HDV activity patterns by vocation.

To improve the characterization of HD activity, EMFAC2017 incorporated the latest finding from UCR CE-CERT HD activity data collection study[66]. The UCR study collected vehicle and engine activity data from 90 heavy-duty vehicles that make up 19 different groups defined by vocation, GVWR and geographic region. The study targeted 2010 or newer heavy duty vehicles that were mostly equipped with SCR technology. For each truck, data were collected using GPS and ECU data loggers at 1Hz resolution for a period of at least one month. The data were cleaned and processed for quality assurance before being used in analysis to produce activity statistics such as engine starts, soak time distribution, and idle hours. Table 4.4-4 shows number of vehicles by vocation and region group included in the final data set.

---

[64] EMFAC2000 Technical Support Documentation, Section 11.0 HDT Activity. Available at https://www.arb.ca.gov/msei/onroad/doctable_test.htm

[65] EMFAC2002 Technical Memos and Support Documents. Extended Idle for Heavy-Duty Trucks. Available at https://www.arb.ca.gov/msei/emfac2002_docs.htm

[66] Boriboonsomsin, K., Johnson, K., Scora, G., Sandez, D., Vu, A., Durbin, T., & Jiang, Y. (2017) Collection of Activity Data from On-Road Heavy-Duty Diesel Vehicles. Available at https://www.arb.ca.gov/research/apr/past/13-301.pdf

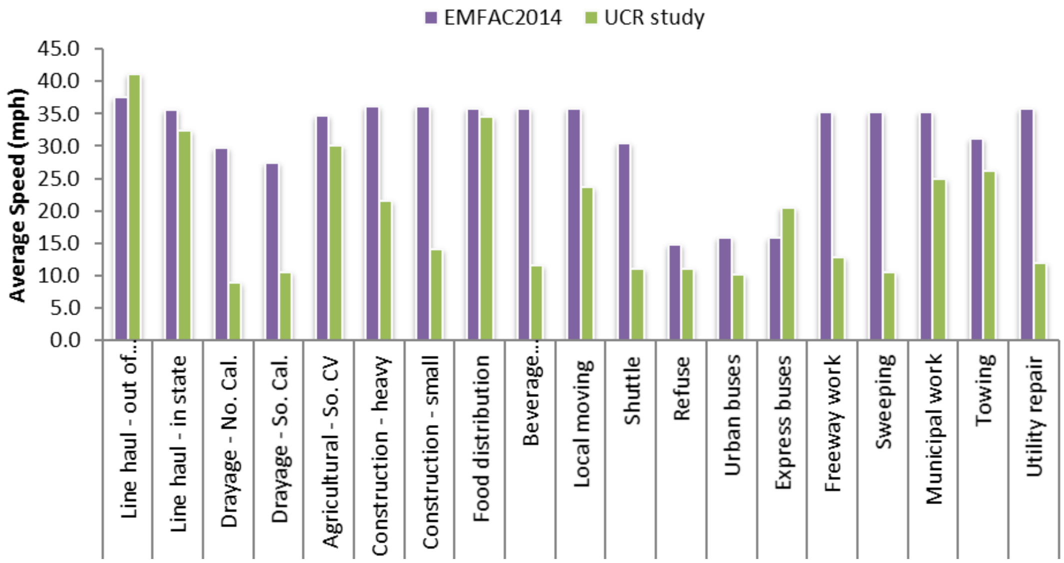
Table 4.4-4: Vehicle Samples in UCR CE-CERT HD Activity Study

Group ID	Vocation - Region Group	Region	Number of Trucks with Completed Data
1a	Line haul - out of state	No. Cal.	3
1b	Line haul - in state	So. Cal.	3
2a	Drayage - No. Cal.	No. Cal.	1
2b	Drayage - So. Cal.	So. Cal	5
3b	Agricultural - So. CV	So. Cal	8
4a	Construction - dump truck/water truck	Both	6
4b	Construction - Cement mixers	Both	5
5a	Food distribution	So. Cal.	5
5b	Beverage distribution	So. Cal.	6
5c	Local moving	So. Cal.	1
6	Shuttle -airport	No. Cal.	5
7	Refuse	No. Cal.	6
8a	Urban buses	No. Cal.	6
8b	Express buses	So. Cal.	5
9a	Freeway work	Both	5
9b	Sweeping	Both	5
9c	Municipal work	So. Cal.	3
9d	Towing	Both	7
10	Utility repair	No. Cal.	5
	Total		90

Notes: No. Cal. = Northern California; So. Cal. = Southern California; CV = Central Valley

Findings from the UCR study affirmed that speed distribution, start, soak and idle activity differ greatly between vocations. For instance, line haul trucks have significantly higher average speed than other categories as they travel more on freeway and highways. In addition, the drayage trucks, shuttles, urban buses and refuse trucks have lowest average speeds due to their vocational needs to spend higher portion of VMT off highways. Figure 4.4-5 demonstrates the difference in average speeds between vocation-region groups, and EMFAC2014 assumptions. Statistics from the UCR study were analyzed and selectively applied to relevant EMFAC HD categories as discussed in the next three sections. Since EMFAC is designed to estimate emissions on an average weekday, these statistics were generated using weekday data.

Figure 4.4-5: EMFAC2014 vs UCR Study Average Speed by Vocation-Region Group



4.4.2.1. UPDATE TO HD SPEED DISTRIBUTION

The speed distribution for HD vehicles refer to the fractions of VMT in each speed bin at a specific hour of day. While the UCR study provides sufficient VMT by speed bin data for each vocation-region group, the small sample size in each group caused concern in using the hourly VMT distribution from this study. Therefore, EMFAC2017 preserved the VMT by hour distribution used in EMFAC2014, but updated the VMT by speed bin distribution at a specific hour of the day. The fraction of VMT in speed bin *s* at hour *i* is calculated as,

$$Fraction_{i,s} = \frac{\%\ of\ daily\ VMT_{i,s}}{\sum_{hour=i} \%\ of\ daily\ VMT_{i,s}} \qquad \text{(Eq. 4.4-2)}$$

The speed distributions were developed for each vocation-region group using the UCR data, and were applied to relevant EMFAC vehicle categories as shown in Table 4.4-5. It should be noted that HD speed distribution update was only applied to regions other than SCAG. For SCAG regions, EMFAC2014 speed profiles for HHDTs and MHDTs were applied as they reflected local modeling results from SCAG truck model.

Data from three vocation-region groups in the UCR study were not used in EMFAC2017 update. Drayage truck in northern California sample contains only one truck, which exhibited abnormal behavior such as high numbers of starts and idle trips, therefore it was not included. Activity profiles for urban buses and express buses are highly dependent on the service and route that buses are assigned to operate, which in turn, are influenced by regional land use and population density. The UCR urban bus samples were from one selected transit agency and may not be representative of statewide urban bus activity.

Table 4.4-5: EMFAC-UCR Vehicle Category Mapping for Speed Distribution

Group ID	UCR Vocation-Region Group	EMFAC Vehicle Categories
1a	line haul OOS	T6 CAIRP, T6 OOS, T7 CAIRP, T7 OOS, Motor coach
1b	line haul IS	T7 tractor
2a	Drayage - No. Cal.	Not used
2b	Drayage - So. Cal.	T7 POAK, T7 POLA, T& other ports
3	Agricultural - So. CV	T6 ag, T7 ag
4	Construction	T6 instate construction, T7 CAIRP construction, T7 Single construction, T7 tractor construction
5	Instate Food, beverage or moving	T6 instate, T7 single, SBUS
6	Shuttle -airport	All Other Buses
7	Refuse	T7 SWCV
8a	Urban buses	Not used
8b	Express buses	Not used
9	Public	T6 public, T7 public
10	Utility repair	T7 Utility

Some of the vocation-region groups were combined into one group to be properly mapped to EMFAC HD category. This includes,

- Vocation-region group 4a and 4b were aggregated to provide weighted statistics for EMFAC construction trucks.
- Vocation-region group 5a, 5b and 5c are merged into one group: local trucks, which represents mostly in-state single trucks.
- Vocation-region group 9a, 9b and 9c are merged into one group to represent public fleet.

Weighting factors used in the aggregation are developed based on annual miles accrued by appropriate vocational trucks reported in VIUS 2002 data[67]. When such data are not available, as in the case for public fleet, sub-groups are weighted equally. The weighting factors are provided in Table 4.4-6.

[67] Vehicle Inventory and Use Survey (2002) Available at https://www.census.gov/svsd/www/vius/2002.html

Table 4.4-6: Weighting Factors in Aggregating UCR Vocation-Region Groups

Aggregated Group ID	Vocation-Region Subgroup ID	Group Description	Weighting factor
4	4a	Construction - dump/water truck	0.585
4	4b	Construction - concrete mixing	0.415
5	5a	Food distribution	0.720
5	5b	Beverage distribution	0.180
5	5c	Local moving	0.100
9	9a	Freeway work	0.333
9	9b	Sweeping	0.333
9	9c	Municipal work	0.333

In general, the new speed profiles reflect drastic difference between vocational groups, and also more VMT at low speeds of less than 15 mph compared to previous assumptions in EMFAC2014.

4.4.2.2. UPDATE TO HD STARTS AND SOAK TIME DISTRIBUTION

In EMFAC2014, HD start emissions are evaluated for two types of starts: warm starts and cold starts. The EMFAC2017 adopted a refined methodology that models start emission rates as a function of soak time, similar to LDVs. Therefore, both number of engine starts per day, and the soak time distribution are critical information to estimate start emissions. The UCR study provided data to generate these statistics by vocation and region group. As discussed earlier for speed distribution, selected vocation-region groups are merged, and then average starts per weekday and soak time distributions specified by vocation-region group were applied to EMFAC vehicle categories using the same mapping as in Table 4.4-5.

The average starts per weekday is provided in Table 4.4-7. These starts are engine-on events that occurred after any duration of soaking time, and includes the engine-on event for idle trips. Data shows that, except for the northern California drayage truck which is considered an outlier, long-distance line hauls trucks have the highest number of starts per day, while refuse trucks and public fleets have the lowest numbers.

Table 4.4-7: Starts per Weekday by Vocation-Region Group

Group ID	Vocation-Region Group	Starts per Weekday
1a	Line haul - out of state	14.6
1b	Line haul - in state	12.7
2a	Drayage - No. Cal.	27.1 (not used)
2b	Drayage - So. Cal.	7.6
3	Agricultural - So. CV	4.4
4	Construction	4.5
5	Instate Food, beverage or moving	11.5
6	Shuttle – Airport	8.4
7	Refuse	3.9
8a	Urban buses	4.2 (not used)
8b	Express buses	8 (not used)
9	Public	3
10	Utility repair	11.5

In addition to starts per weekday, the hourly distribution of HD starts was also generated for each vocation-region group. It is calculated as the percentage of the total starts in each of the 24 hours on weekdays.

The soak time distribution is defined as the fraction of starts with preceding soak time in one of the 19 soak time bins at a specific hour of day. The soak time bins definition, and the soak time distributions are provided in Appendix 6.14 for line haul and drayage trucks. The rest of these distributions can be found in HD activity data collection study report[68]. For most vocations, the soak time distribution is dominated by short soaking events of less than 5 minutes. Public fleets have smaller fractions of short soak events and greater fractions of 12 hour and longer soaking, likely due to less frequent operation.

4.4.2.3. UPDATES TO HD IDLE HOURS

The HD idling hours refers to time spent in extended idling activity that usually occur at trip origins and destinations such as work site, or at rest stops. HD idle activity should not be confused with short en-route idling such as stopping at a traffic light. HD idle activity is defined as one of the following two types of events:

- **Idle Trip:** A trip (engine on to engine off) with an average speed of 5 mph and lower and a trip distance of less than 5 miles.
- **Extended Idling Event:** A continuous segment of vehicle activity that meets three criteria: all instantaneous vehicle speeds being lower than 5 mph, the total distance of less than 1 mile, and the total duration of more than 5 minutes.

Under the California truck idling regulation, heavy heavy-duty diesel trucks' idle hours per day vary by both calendar year and model year, as presented in Table 4.4-8. For the rest heavy

[68] Boriboonsomsin, K., Johnson, K., Scora, G., Sandez, D., Vu, A., Durbin, T., & Jiang, Y. (2017) Collection of Activity Data from On-Road Heavy-Duty Diesel Vehicles. Available at https://www.arb.ca.gov/research/apr/past/13-301.pdf

duty fleets, including all medium heavy-duty vehicles, the idle hours per day is a set value depending only on vehicle category, as presented in Table 4.4-9. The idle hours from the UCR study were examined closely and updates were made only for selected categories where data were relevant and results were reasonable compared to other empirical data. These updated categories include T7 construction, T7 Ag and T7 single trucks of 2008 and later model year in calendar year 2008 and later, and all public, utility and SWCV fleets. For the rest of the HD fleets, or fleet of pre-2008 model year, EMFAC2014 assumptions were applied.

Table 4.4-8. EMFAC2017 Idle Hours for Selected HHDT Categories

EMFAC Vehicle Class	Calendar Year Range	Model Year Range	EMFAC2014 Idle Hours per Day	EMFAC2017 Idle Hours per Day
T7 CAIRP	pre 2005	pre 2008	4.41	4.41
T7 CAIRP	2005-2007	pre 2008	4.28	4.28
T7 CAIRP	2005-2007	2008+	4.28	4.28
T7 CAIRP	2008+	pre 2008	0.22	0.22
T7 CAIRP	2008+	2008+	4.41	4.41
T7 OOS	pre 2005	pre 2008	5.47	5.47
T7 OOS	2005-2007	pre 2008	5.43	5.43
T7 OOS	2005-2007	2008+	5.43	5.43
T7 OOS	2008+	pre 2008	0.21	0.21
T7 OOS	2008+	2008+	5.47	5.47
T7 Construction	pre 2005	pre 2008	0.79	0.79
T7 Construction	2005-2007	pre 2008	0.37	0.37
T7 Construction	2005-2007	2008+	0.37	0.37
T7 Construction	2008+	pre 2008	0.25	0.25
T7 Construction	2008+	2008+	0.79	0.67
T7 Ag	pre 2005	pre 2008	0.79	0.79
T7 Ag	2005-2007	pre 2008	0.37	0.37
T7 Ag	2005-2007	2008+	0.37	0.37
T7 Ag	2008+	pre 2008	0.25	0.25
T7 Ag	2008+	2008+	0.79	0.31
T7 Tractor	pre 2005	pre 2008	0.79	0.79
T7 Tractor	2005-2007	pre 2008	0.37	0.37
T7 Tractor	2005-2007	2008+	0.37	0.37
T7 Tractor	2008+	pre 2008	0.25	0.25
T7 Tractor	2008+	2008+	0.79	0.79
T7 Single	pre 2005	pre 2008	0.79	0.79
T7 Single	2005-2007	pre 2008	0.37	0.37
T7 Single	2005-2007	2008+	0.37	0.37
T7 Single	2008+	pre 2008	0.25	0.25
T7 Single	2008+	2008+	0.79	0.92

Table 4.4-9. EMFAC2017 Idle Hours for Selected Categories

EMFAC Vehicle Class	Idle Hours per Day	
	EMFAC2014	EMFAC2017
MCH	1.687	1.687
OB	0.098	0.098
SB	0.53	0.53
T6	0.098	0.098
Public	1.2	0.51
Utility	1.2	0.268
T7 SWCV	1.2	0.633
T7 POAK	1.107	1.107
T7 POLA	1.38	1.38
T7 other port	0.69	0.69

4.4.2.4. HD MILEAGE ACCURAL RATES

HDV mileage accrual rates in EMFAC2017 are similar to those in EMFAC2014, which were based on EMFAC2011 rates. HDV mileage accrual rates in EMFAC2011 were primarily based on data from the Vehicle Inventory and Use Survey (VIUS)[69], which were supplemented with CARB survey data, as, documented in the 2008 Truck and Bus (T&B) Technical Appendix.[70] However, Ag trucks in EMFAC2014 were more specifically defined than in EMFAC2011. Only those trucks, reported in TRUCRS as having the Ag truck designation are eligible for the Truck and Bus Ag provision. As updated in EMFAC2014, Ag truck mileage accrual rates were based on their mileage reported in TRUCRS. To incorporate the low-mileage work truck provisions, VIUS/CARB survey data were used to compute mileage accrual rates for each mileage threshold sub-vehicle class grouping.

For EMFAC2017, it was determined that T6 "heavy" vehicle classes for the class 7 trucks with GVWR above 26,000 pounds would pull more similar types of trailers and loads as the class 8 trucks with GVWR above 33,000 pounds, as opposed to the class 4-6 trucks with GVWR of 14,001 to 26,000 pounds. Thus, the following vehicles classes on the left were updated to use the accrual rates of the vehicle classes to the right:

- T6 Instate Heavy now uses T7 Tractor Accrual Rates
- T6 OOS Heavy now uses T7 NOOS Accrual Rates
- T6 CAIRP Heavy now uses T7 CAIRP Accrual Rates
- T6 Instate Construction Heavy now uses T7 Tractor Construction Accrual Rates

An additional update was made for accrual rates that had been extrapolated for older ages in EMFAC2014. The VIUS survey only provided mileage accrual for the ages of zero to fifteen.

[69] https://www.census.gov/svsd/www/vius/products.html
[70] Table 1 in http://www.arb.ca.gov/regact/2008/truckbus08/appg.pdf cites sources used to derive mileage accrual rates.

For EMFAC2017, it was decided to avoid the extrapolation at older ages and to assume that the age 15+ trucks have similar accrual rates as the age 15 vehicles. This should not have a significant impact on emissions as the population of the age 15+ trucks are relatively small, and as a result of the Truck and Bus Rule, they are all certified to the same standard.

For EMFAC202x, there are projects underway from which updates to the HDV mileage accrual rates will be made as is appropriate. CalTrans has a CalVIUS survey[71] underway that has questions designed to obtain annual freight truck activities specific to California. This CalVIUS survey was developed to fill the gap created by the discontinuance of the federal VIUS survey[72] process. Additionally, CARB has a contract in process to examine potential sources of HDV accrual rate data for designated fleet types based on vocations and weight classes. All such sources of information for assessing and updating the current EMFAC HDV accrual rates will be reviewed for the next EMFAC version.

4.4.3. UPDATE TO VMT SPATIAL ALLOCATION

In order to properly account for the inter-sub-area traffic VMT, EMFAC2014 utilized data from Caltrans Highway Performance Monitoring System (HPMS)[73] to regionally distribute VMT associated with light duty vehicles. The EMFAC2014 methodology is described in section 3.3.3.2.2 of EMFAC2014 Technical Support Documentation. For EMFAC2017, CARB staff utilized data from California Vehicle Activity Database (CalVAD) to better allocate light duty vehicle VMT to different GAI within the state of California. Details of this analysis is provided in Appendix 6.15.

4.5.FORECASTING

4.5.1. UPDATE ON FORECASTING STATEWIDE NEW LDV SALES

In EMFAC2017, the annual vehicle population is comprised of vehicles retained from the prior CY, plus new vehicle sales. The retained vehicles are calculated by applying vehicle survival rates to the prior year's vehicle population. To forecast new vehicle sales, first the statewide new vehicle sales need to be estimated. And then the statewide new vehicle sales need to be disaggregated to regional level new sales, by sub-area. For EMFAC2017, the forecasting equation for statewide new sales of LD vehicles, for all fuel types, was developed using a regression analysis, based on historical time-series data from 1995 – 2016.

In this econometric modeling process, the selection of variables aimed to be consistent with microeconomic theory which dictates that attention must be paid to the reasonableness of coefficient magnitudes and signs. The goodness of fit and significance criteria (such as t-statistic) from potential models, using different variable combinations, also had to be considered. CARB staff conducted a number of statistical modeling experiments and eventually selected the best available model for forecasting statewide new LD vehicle sales for use in

---

[71] http://www.dot.ca.gov/hq/tpp/offices/omsp/statewide_modeling/cal_vehicle_survey.html
[72] https://www.census.gov/svsd/www/vius/2002.html
[73] GIS based NTAD data was populated by HWA using HPMS link level data.

EMFAC2017. The same criteria for statistical modeling were applied to all of CARB's regression analysis efforts, including new vehicle sales, LDV VMT growth trends, and HD VMT growth trends, as discussed in subsequent sections.

The primary data sources used for this analysis included UCLA Anderson Forecast (UCLA), California Department of Finance (DOF), and DMV. Below is a more detailed list for the sources used in this regression development, spanning the years 1995 – 2016, and in the forecasting equations, starting in 2017. All data variables used were on a statewide, annual basis. A summary of primary data sources is provided in Table 4.5-1.

Table 4.5-1. Primary sources of data used for EMFAC2017 new vehicle sales forecasting.

Data	Source
New vehicle sales (NEW_SALES)	DMV and DOF (1995-2016).
Human population (POP)	DOF (1995-2016), DOF (2017-2050).
Unemployment rate (UR)	DOF (1995-2016), UCLA (2017-2027).
U.S. National housing starts (HS_STRT_US)	DOF (1995-2016), UCLA (2017-2027).

The chosen regression model for new LD vehicle sales at the statewide level is as follows.

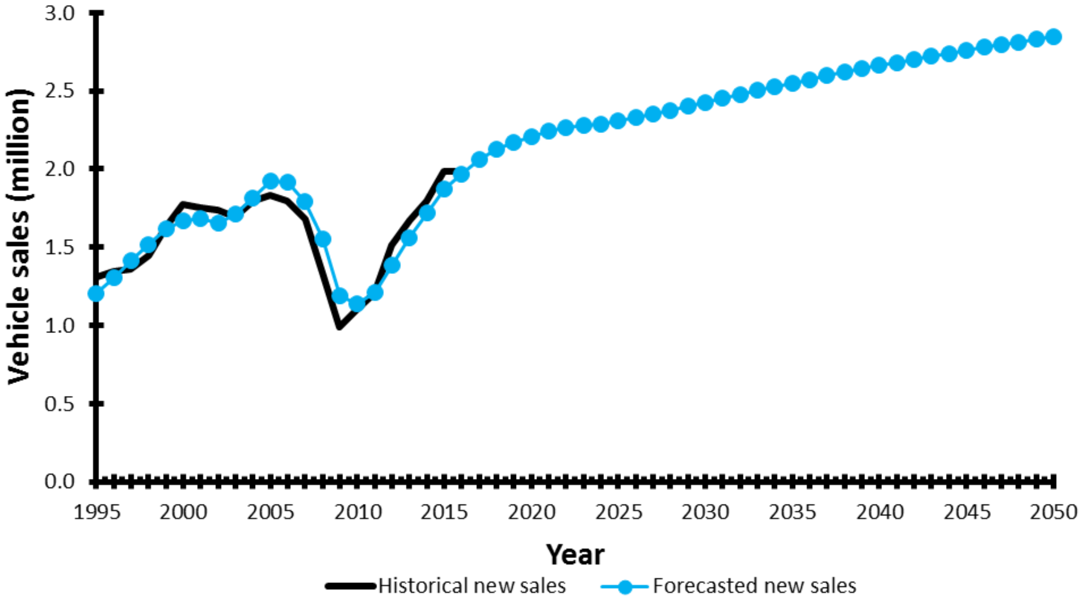
$$NEW\_SALES\_FORECAST = -1.137 - 0.0757xUR + 0.0816xPOP + 0.000259xHS\_STRT\_US \quad \text{(Eq.4.5-1)}$$

where:

NEW_SALES_FORECAST – forecasted statewide new sales of LD vehicles, regardless of fuel type, in millions;
UR – statewide unemployment rate, in percentage;
POP – statewide human population, in million persons; and
HS_STRT_US – National housing starts, in thousand units.

Figure 4.5-1 shows that the forecasted statewide new sales, predicted by the regression model, which fits the existing data from 1995 – 2016 reasonably well, even with the anomaly due to the significant recession during this time period (for which some variance can be seen). The figure below also presents the forecasted statewide sales for years 2017 – 2050 using the selected regression model.

Figure 4.5-1: The Historical and the Regression-Model Forecasted Statewide New Sales of LD Vehicles, including All Fuel types



4.5.2. UPDATE ON FORECASTING LIGHT DUTY VMT

Default VMT of light duty vehicles at the statewide level is forecasted using a regression analysis, based on historical time-series data from 2000-2016. Similar practice as in the new vehicle sales forecasting was also employed to develop forecasting models for light duty VMT. For this econometric modeling, it was assumed that historical light duty vehicles VMT has followed similar trend as statewide gasoline consumptions. Therefore, in the absence of any fuel efficiency improvement, the growth motor vehicle gasoline consumptions should be directly correlated to the growth of light duty vehicle VMT. It needs to be noted that light duty vehicles in California are the major consumers of motor vehicle gasoline.

The primary data sources used for this analysis included UCLA Anderson Forecast (UCLA), California Department of Finance (DOF), California Board of Equalization (BOE), California Energy Commission (CEC), U.S. DOE Energy Information Administration (EIA), and U.S. Bureau of Economic Analysis (BEA). Table 4.5-2 provides a more detailed list of sources used in this regression development, spanning the years 2000-2016, and in the forecasting equations, starting in 2017. All data variables used were on a statewide, annual basis.

Table 4.5-2. Primary sources of data used for EMFAC2017 Light Duty VMT forecasting.

Data	Source
Motor gasoline sales (GAS)	DOF and BOE (2000-2016).
Gasoline retail price (GAS_PRICE)	CEC (2000-2012), EIA (2013-2016), CEC (2017-2030).
Human population (POP)	DOF (2000-2016), DOF (2017-2050).
Unemployment rate (UR)	DOF (2000-2016), UCLA (2017-2027).
U.S. National housing starts (HS_STRT_US)	DOF (2000-2016), UCLA (2017-2027).
Consumer Price Index (CPI)	DOF (2000-2016), UCLA (2017-2027).

The chosen regression model for annual VMT of light duty vehicles at the statewide level is:

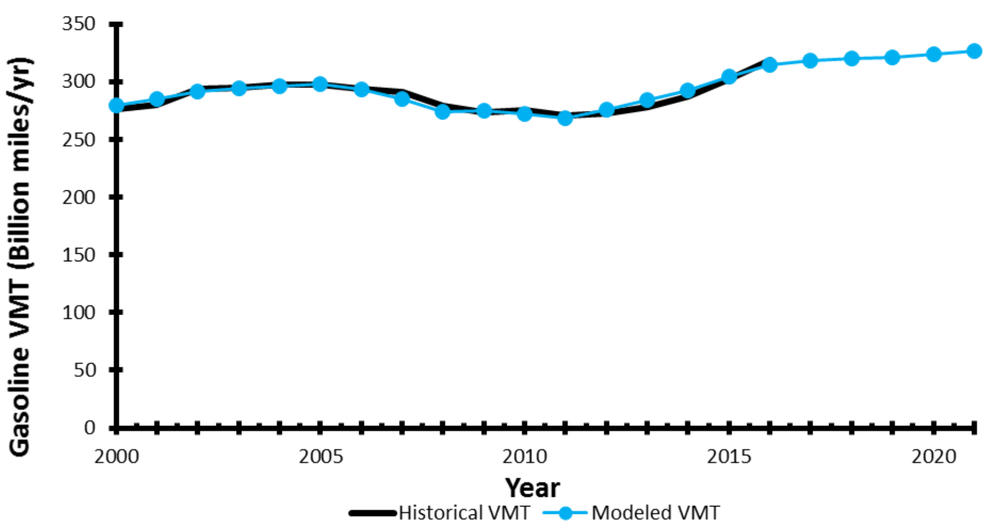
GAS_VMT_FORECAST= -12.52 – 10.24xGAS_PRICE + 0.0176xHS_STRT_US – 1.079xUR + 8.638xPOP (Eq. 4.5-2)

where:

GAS_VMT_FORECAST – forecasted statewide annual VMT of gasoline and electric vehicles, in billion miles per year;
GAS_PRICE – statewide annual average gasoline price, in 2015 dollars per gallon;
UR – statewide unemployment rate, in percentage;
POP – statewide human population, in million persons; and
HS_STRT_US – National housing starts, in thousand units.

As shown in Figure 4.5-2, the VMT regression model provided a good fit between observed and predicted data. By including socio-economic factors in the model, the impact of the economic downturn was reflected. EMFAC2017 uses the regression-developed VMT growth trend for the 5-year short-term, i.e., 2017-2021. For 2022-2050, EMFAC2017 uses DOF's human population forecast data to represent the VMT growth trend. For years 2000-2016, EMFAC2017 uses BOE's historical data on taxable gasoline fuel sales to normalize the statewide VMT rates.

Figure 4.5-2: Statewide Motor Gasoline Consumption Forecasts using Regression Analysis



4.5.3. UPDATES ON FORECASTING HEAVY DUTY VEHICLE VMT

Similar to light duty VMT, it is assumed that historical diesel consumptions in California is directly correlated to VMT associated with heavy duty vehicle VMT as they are the major consumer of taxable diesel in California. Therefore, in the absence of any diesel fuel efficiency improvement, the growth in future diesel fuel consumption should be directly correlated with heavy duty vehicle VMT. As a result, CARB staff developed econometric models to estimate future diesel consumption in California.

On-road diesel consumption, at the statewide level, is forecasted using a regression model that is based on historical time-series data from 1995-2016. The regression model's statewide diesel fuel growth rates are used in EMFAC2017 to forecast the statewide diesel VMT as discussed in more detail below. CARB staff conducted a number of statistical modeling experiments and eventually selected the best available variables to represent forecasted statewide diesel fuel sales, for use in EMFAC2017, based upon the model's ability to simulate historical data. The regression model, for statewide diesel fuel consumption is characterized by the following equation:

$$DSL\_FORECAST=1.353 + 1.140*DIS\_INC - 0.0543*UR \qquad \text{(Eq. 4.5-3)}$$

where:

DSL_FORECAST – forecasted statewide annual diesel consumption, in billions of gallons;
DIS_INC – f state disposable personal income, in trillions of 2015 dollars; and
UR – f statewide unemployment rate, in percentage.

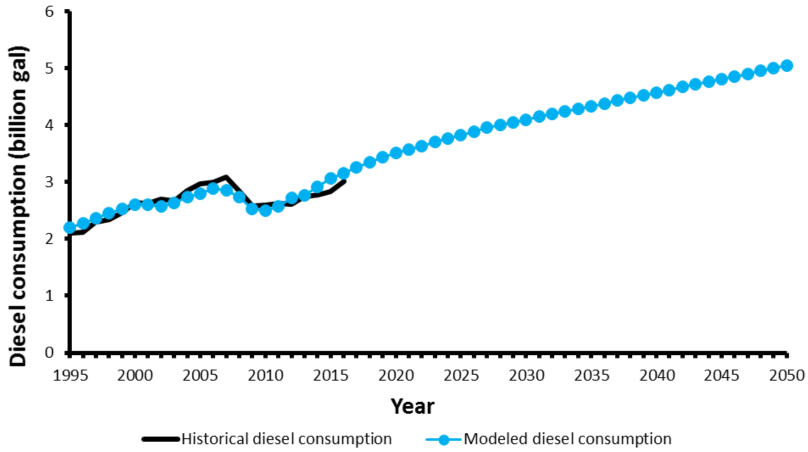
The primary data sources included UCLA Anderson Forecast (UCLA), California Department of Finance (DOF), California Board of Equalization (BOE), and U.S. Bureau of Economic Analysis (BEA). Table 4.5-3 provides a more detailed list of the sources used. All data variables used were on a statewide, annual basis.

Table 4.5-3. Primary sources of data used for EMFAC2017 Heavy Duty VMT forecasting.

Data	Source
Motor diesel sales (DSL)	DOF and BOE (1995-2016).
Disposable personal income (DIS_INC)	BEA (1995-2016), UCLA (2017-2027)
Unemployment rate (UR)	DOF (2000-2016), UCLA (2017-2027).
Consumer Price Index (CPI)	DOF (2000-2016), UCLA (2017-2027).

As shown in Figure 4.5-3 this diesel consumption regression model provided a good fit between observed and predicted data. The figure below also shows the statewide diesel consumption forecasts, for 2017-2050, using the selected regression model. By including socio-economic factors in the model, the impact of the historical economic downturn was reflected in the forecasted diesel consumption growth rates. The regression model's statewide diesel fuel growth trend is used in EMFAC2017 to forecast the statewide diesel VMT.

Figure 4.5-3: Statewide Diesel Consumption Forecasts Using Regression Analysis



Similar to EMFAC2014, EMFAC2017 uses the resulting diesel consumption trend discussed above to derive the statewide VMT HD vehicle growth rates for years 2017 – 2050. For years 2000-2016, EMFAC2017 uses BOE's historical data on taxable diesel fuel sales to normalize the statewide VMT rates.

Forecasting HD VMT in EMFAC2017 follows the same methodology as with EMFAC2014. Although there is no methodological change, the underlying data have been significantly updated as described below.

Ag Trucks

For HD diesel trucks that opt to use the agricultural truck provision specified by the Truck and Bus rule,[74] EMFAC2017 assumes that their total VMT will stay constant over time. This assumption is supported by the fact that these trucks are exempt from the rule requirements up to 2017/2023 as long as they were reported to the CARB by January 31, 2014.

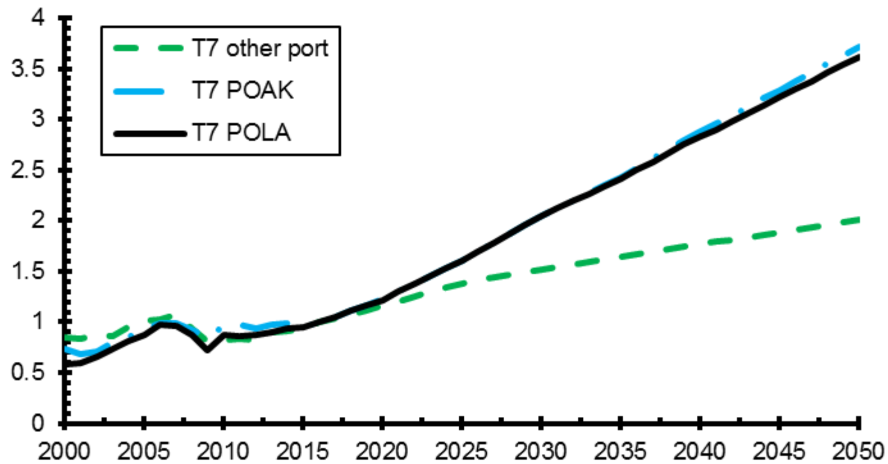
Drayage Trucks

As with EMFAC2014, EMFAC2017 keeps using the activity growth rates from CARB's Ocean-Going Vessel (OGV) model[75] as a surrogate for future drayage truck VMT growth. The OGV growth trend is based on the 2013 Federal Highway Administration (FHWA) Freight Analysis Framework (FAF) forecast which provides freight tonnage, by commodity type, for various port regions in California out to 2040. The FAF's forecast is linearly extended from 2040 to 2050 to be consistent with EMFAC2017's calendar year range 2000-2050. For historical years of 2000-2015, EMFAC2017 uses the container counts (in TEUs) from the ports of Los Angeles, Long Beach and Oakland. The historical TEU data of the three ports have been updated using the American Association of Port Authorities (AAPA) data.

[74] http://www.arb.ca.gov/msprog/onrdiesel/documents/fsag.pdf
[75] https://www.arb.ca.gov/msei/2014-updates-to-the-carb-ogv-model.docx

For the “Other Ports” drayage truck category, EMFAC2017 also assumes that VMT grows similar to the diesel fuel use trend, with the assumption that every 1 percent growth in diesel fuel use is equivalent to 1.5 percent growth in “Other Ports” drayage trucks VMT. Figure 4.5-4 shows the VMT growth rates used in EMFAC2017 for drayage trucks.

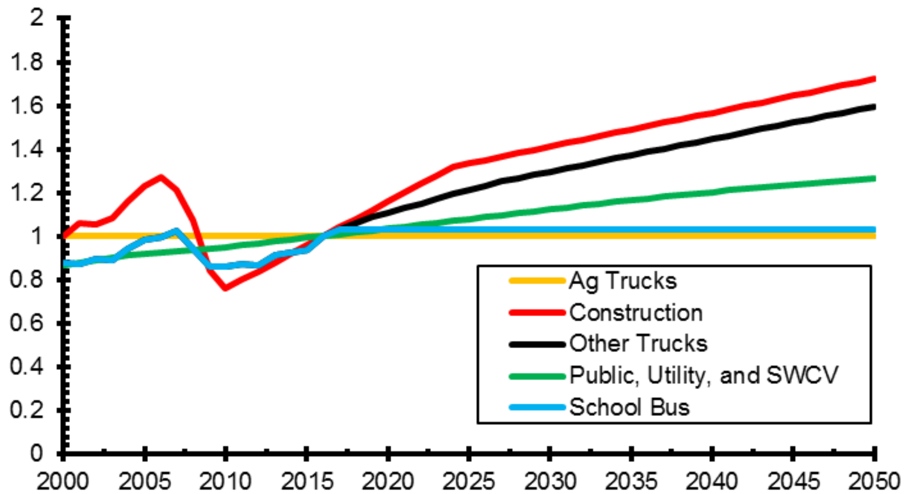
Figure 4.5-4 VMT Growth Trend for Drayage Trucks



<u>Construction, Public, Utility and Solid Waste Collection Vehicles (SWCV) and School Buses</u>

The VMT of Construction, Public, Utility and Solid Waste Collection Vehicles (SWCV) and school buses in EMFAC2017 is assumed to follow the same activity growth trend as in EMFAC2014 except that the updated DOF based statewide human population is used. Details on EMFAC2017 VMT growth rates are provided in section 3.3.4.3.3.2 of EMFAC2014 Technical Support Documentation.

Figure 4.5-5 HD VMT Growth Trend in EMFAC2017



4.5.4. FORECASTING ZEV POPULATION

EMFAC2017 is being updated to reflect the latest available information on future ZEV sales. In a general sense, the ZEV fractions reflects the strategy by which the light duty vehicle manufacturers take to comply with CARB ZEV mandate. The 2017+ future projections are based upon the Mid-Range Scenario of the Advanced Clean Cars Midterm Review (Appendix A[76]). To reflect the new assumption in EMFAC, for each model year, staff calculated the fraction of the fleet that will operate similar to a pure zero emission vehicles. This fraction is called EV fraction and is equivalent to the sum of populations of Battery Electric Vehicles (BEVs), Fuel Cell Electric Vehicles (FCEVs), and the fraction of Plug-in Hybrid Electric Vehicles (PHEVs) population that operate like pure ZEVs, divided by the total population of Gasoline and electric fleet. To estimate the fraction of PHEVs that operates like pure ZEVs, EMFAC utilizes utility factors, which are defined as the fraction of VMT the PHEV obtains from the electrical grid. EMFAC2014 was assuming a constant utility factor of 0.4 for all model years of PHEVs, while in EMFAC2017 this fraction is more dynamic and varies by model years from 0.46 for MY2018 to 0.6 for MY2025+. Table 4.5-4 shows the EMFAC2014 fractions of each model year that were EV (as opposed to gasoline). This is documented in the EMFAC2014 technical support documentation[77] under section 3.3.3.3.1.

---

[76] https://www.arb.ca.gov/msprog/acc/mtr/appendix_a.pdf
[77] https://www.arb.ca.gov/msei/downloads/emfac2014/emfac2014-vol3-technical-documentation-052015.pdf

Table 4.5-4 EMFAC2014 Percentage of Market Shares with the ZEV Mandate

Model Year	Market Share of Electric LDA	Market Share of Gasoline LDA
2010	0.08%	99.92%
2011	0.08%	99.92%
2012	0.95%	99.05%
2013	0.97%	99.03%
2014	0.98%	99.02%
2015	1.94%	98.06%
2016	2.05%	97.95%
2017	2.06%	97.94%
2018	3.94%	96.06%
2019	6.01%	93.99%
2020	7.92%	92.08%
2021	9.75%	90.25%
2022	11.36%	88.64%
2023	12.98%	87.02%
2024	14.43%	85.57%
2025+	15.71%	84.29%

The Advanced Clean Cars Midterm Review (Appendix A) estimated the number of ZEVs that would need to be produced for each model year to meet CARB regulatory goals. These were further divided into BEVs, FCEVs, and PHEVs. Table 4.5-5 was generated using the updated utility factors applied to the ZEV populations estimated through appendix A of the Advanced Clean Cars Midterm Review. For years prior to 2017, the actual EV populations from DMV vehicle registration database will be used.

Table 4.5-5 EMFAC2017 Percentage of Market Shares with the ZEV Mandate

Model Year	PC	LDT1	LDT2	MDV
2017	2.5%	0.3%	1.5%	0.4%
2018	2.5%	0.3%	1.5%	0.4%
2019	2.5%	0.7%	1.5%	1.0%
2020	3.2%	1.5%	1.7%	2.0%
2021	3.6%	2.4%	2.8%	3.2%
2022	4.3%	2.9%	3.3%	3.8%
2023	5.0%	3.3%	3.7%	4.3%
2024	5.7%	3.6%	4.2%	4.8%
2025 +	6.3%	4.0%	4.6%	5.3%

Originally, it was anticipated that only passenger cars (PCs) would penetrate significantly the electric vehicle fleet. The above tables suggest that fewer PC EVs will be necessary to meet ZEV mandate relative to the assumptions of EMFAC2014. However, the truck fleet will offset this somewhere with gradually increasing EV fraction. Most of this is results from the opinion that the electric range of the BEVs and PHEVs will continue to increase across all categories.

5. EMISSIONS IMPACT

5.1. BASICS

As described earlier in this document, EMFAC2017 retains some of the EMFAC2014 updates but also has some unique additions. Some of the noteworthy updates to the EMFAC2017 include:

1. Use of DMV and IRP data from years 2000 through 2016 along with various other data sources to accurately characterize light and heavy duty fleet
2. Development of transit, GHG, and natural gas modules
3. Updates to light duty emission rates methodology (both running and start exhaust emissions)
4. Utilization of latest chassis dynamometer and PEMS data to update heavy duty emission rates
5. Utilization of California Household Travel Survey and UCR heavy duty vehicle activity study data to update activity profiles for light and heavy duty vehicles respectively

To examine the impact of these updates, this section presents plots of emissions, vehicle populations, and VMT. A comparison is made between emission and activity estimates from EMFAC2014 and those estimated using EMFAC2017, at the statewide level. In order to better explain the differences, separate comparisons are made for LD and HD vehicles. The EMFAC2017 results presented in this section were generated using default VMT data. Please note that CARB’s SIP inventory is based on VMT and speed profiles provided by Metropolitan Planning Organizations, which might be different from EMFAC default VMT.

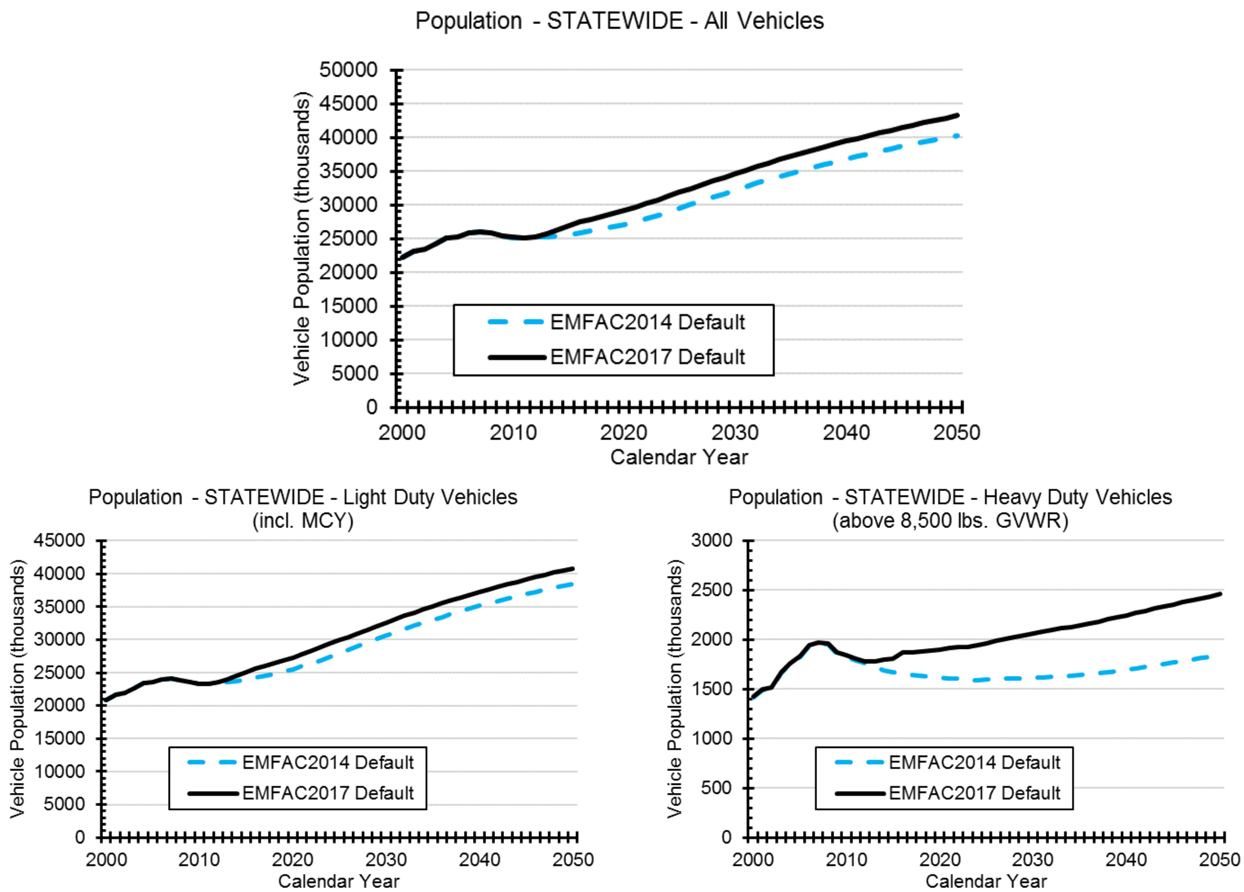
Similar comparisons have been performed for the South Coast and San Joaquin Valley Sub-Areas; and, the explanations provided for the statewide results also apply to these regions. The charts for these intra-regional comparisons are not presented in this section, but are provided in Appendix 6.16.

This section compares the statewide results of EMFAC2017 with EMFAC2014 for vehicle populations (in millions), VMT (in million miles per day) and Emissions (in tons per day). Differences in the results between the two model versions are discussed below.

5.1.1. VEHICLE POPULATION

The panels of Figure 5.1-1 compare EMFAC2014 and EMFAC2017 total HD and LD vehicle populations. The EMFAC2017 total vehicle population, which is dominated by LD vehicles, is slightly higher than the EMFAC2014. The statewide HD population in EMFAC2017 tend to be generally is similar to EMFAC2014 until 2012, after which it is higher than that predicted by EMFAC2014.

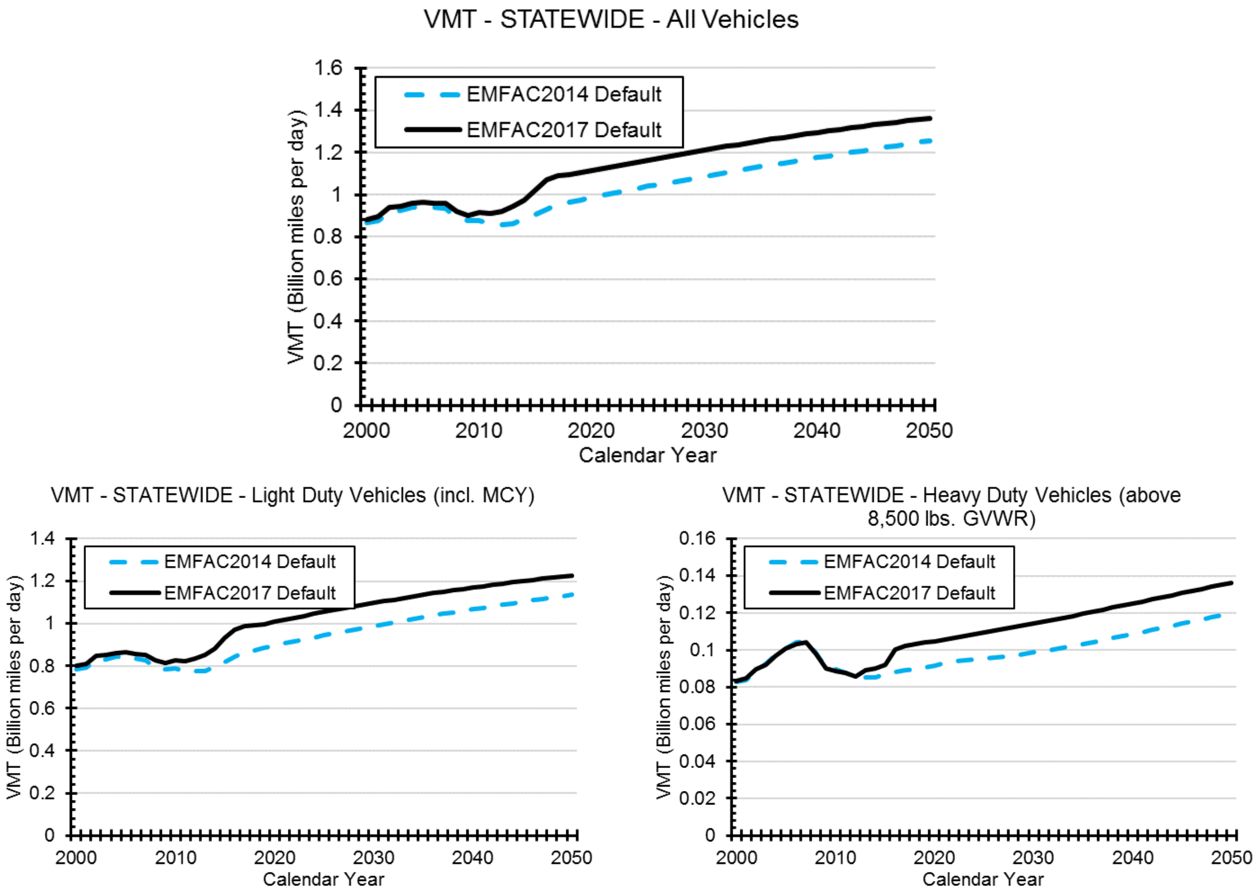
Figure 5.1-1: Comparison of Vehicle Population between EMFAC2014 and EMFAC2017



5.1.2. VMT

Figure 5.1-2 shows a comparison of statewide VMT from EMFAC2014 and EMFAC2017 in billion miles per day. EMFAC2017 shows higher VMT as compared to EMFAC2014 output statewide for all vehicles. For both LD and HD vehicles, the VMT is estimated to be higher than EMFAC2014 mainly due to higher observed fuel consumptions in years 2013 – 2016 as reported by BOE. EMFAC2014 had to make some assumptions about the economic recovery and the increased VMT in the EMFAC2017 update are a positive economic sign.

Figure 5.1-2: Comparison of VMT between EMFAC2014 and EMFAC2017



5.1.3. EMISSIONS

In general, EMFAC2017 shows higher PM and NO_X emissions than EMFAC2014. The NO_X emission increase is primarily attributable to increase in HD ZMR and high speed emission rates in addition to higher HD idle emission rates. Even though start emission rates for HD has dropped, a readjustment to truck and bus compliance assumptions combined with updated activity data predicts higher NO_X emissions in future. For LD vehicles, newer vehicles exhibit higher cold start emissions. While these vehicles do have lower running emissions, the updated emission rates and technology penetration assumptions in EMFAC2017 will lead to a NO_X increase for LD vehicles in future.

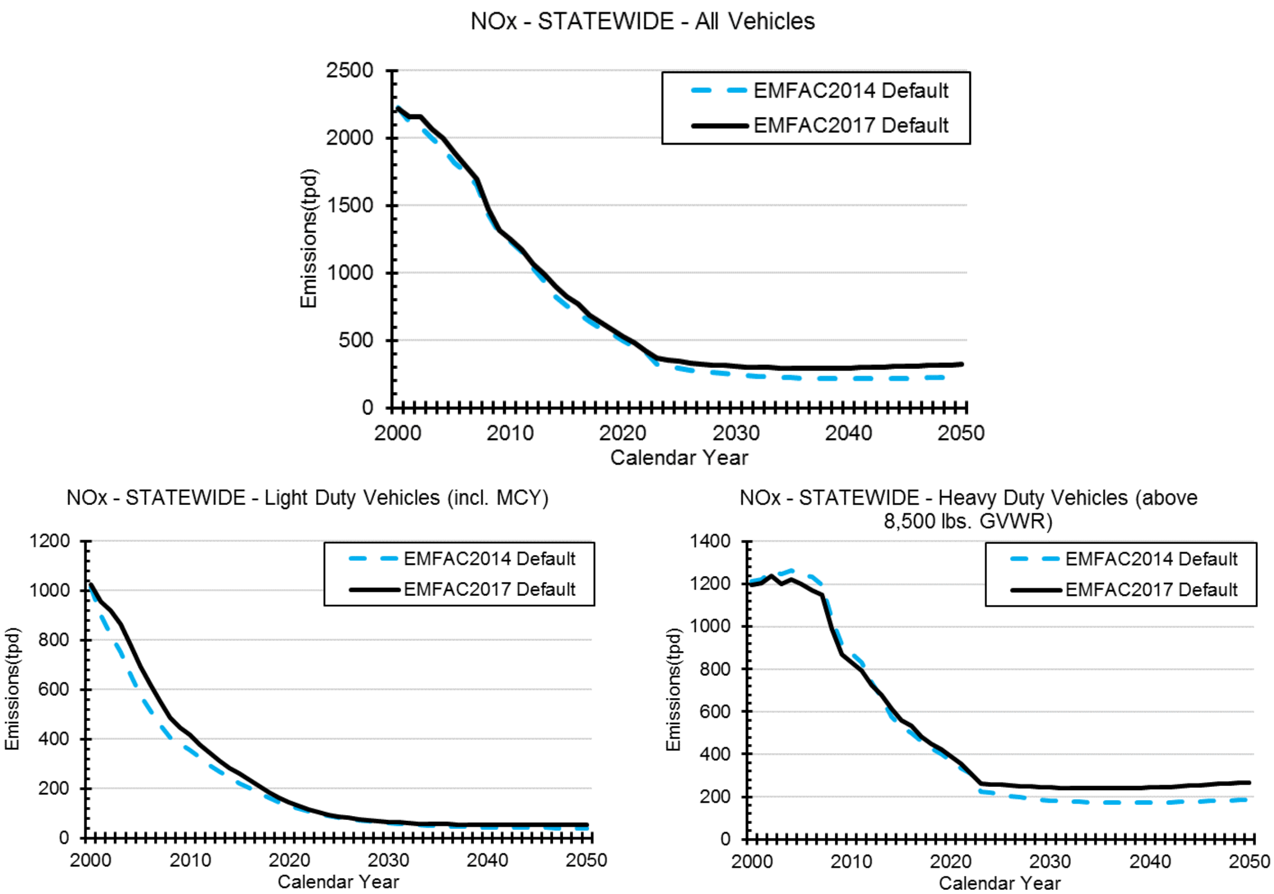
For PM, future HD emissions increase due to increased deterioration rate in EMFAC2017, increased emission rates at higher speeds and adjustments to truck and bus compliance assumptions. These factors combined with updated activity assumptions will lead to additional PM emissions in future. The PM2.5 emissions for LD in future are predicted to be lower.

5.1.3.1. NO_X

Figure 5.1-3 shows the comparison of estimates of statewide NO_X emissions between EMFAC2014 and EMFAC2017, in tons per day. As can be seen in the charts, EMFAC2017 results show slightly higher NO_X emissions in years 2000 through 2007 due to higher pre LEV emission rates.

From 2008 to 2022, while NO_X emissions as projected by EMFAC2017 increase due to adjustments to truck and bus compliance and updates to light duty emission rates, this increase is countered by lower HD start emissions and updates to transit bus emission rates, making EMFAC2017 emissions comparable to EMFAC2014 output. Beyond 2023, the emissions projected by EMFAC2017 are higher due to higher HD emission rates and higher high speed NO_X emissions as described in section 4.3.2.

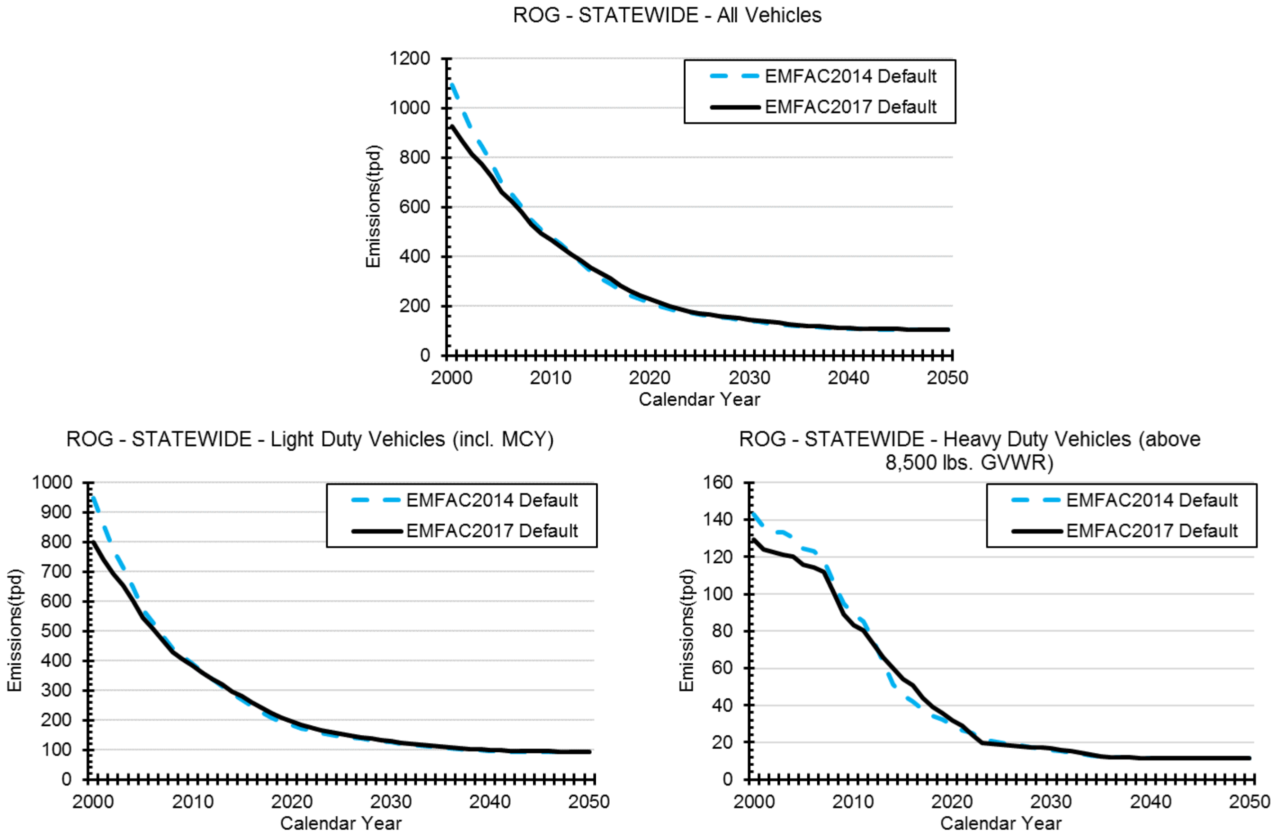
Figure 5.1-3: Comparison of NO_X emissions between EMFAC2014 and EMFAC2017



5.1.3.2. ROG

Figure 5.1-4 shows a comparison of EMFAC2017 and EMFAC2014 estimates of statewide ROG emissions. As shown in the charts, EMFAC2017 ROG is dominated by LD vehicles. The results also show that EMFAC2017 ROG results are lower than EMFAC2014 due to lower number of LD trips/day.

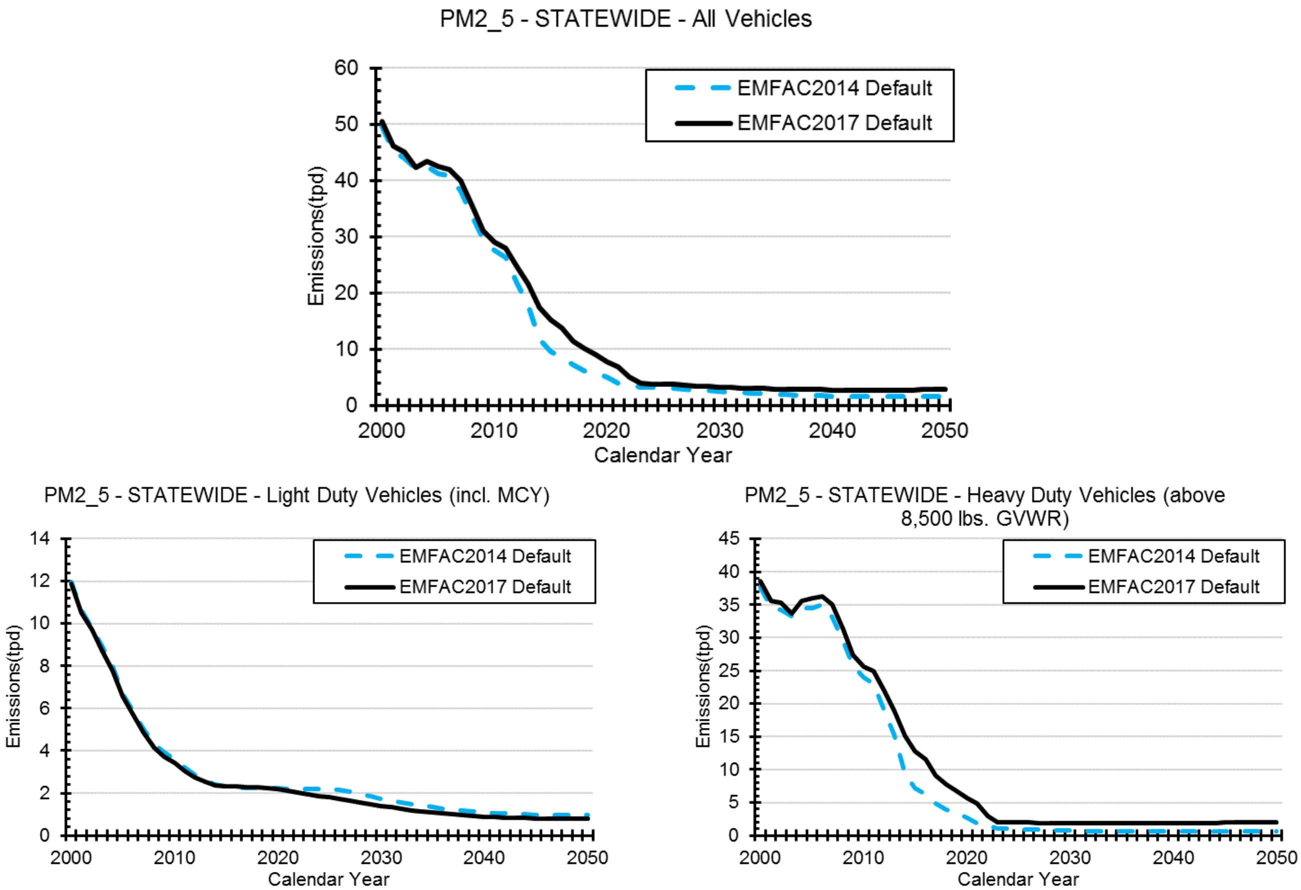
Figure 5.1-4: Comparison of ROG emissions between EMFAC2014 and EMFAC2017



5.1.3.3. PM2.5

Figure 5.1-5 shows the comparison of estimates of statewide total (tailpipe) PM2.5 emissions between EMFAC2017 and EMFAC2014. As evident PM2.5 as predicted by EMFAC2017 for LD vehicles is lower than EMFAC2014 for all years shown in the figure. For HD vehicles, there is an increase in HD emissions between 2012 and 2023 due to adjustments to truck and bus compliance assumptions. Beyond that, the increase in PM2.5 emissions for HD vehicles is driven by higher PM2.5 emissions at high speed and higher deterioration rate.

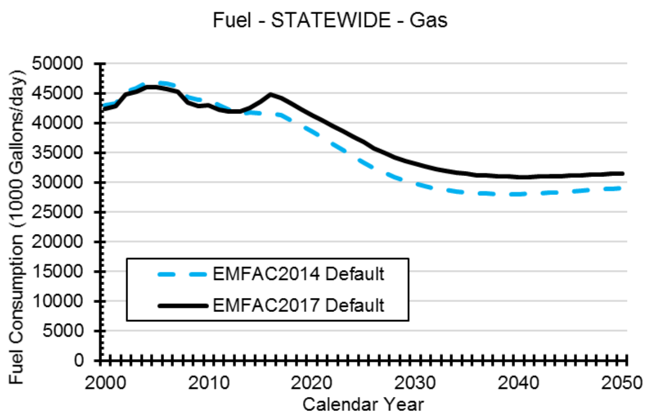
Figure 5.1-5: Comparison of tailpipe PM2.5 emissions between EMFAC2014 and EMFAC2017

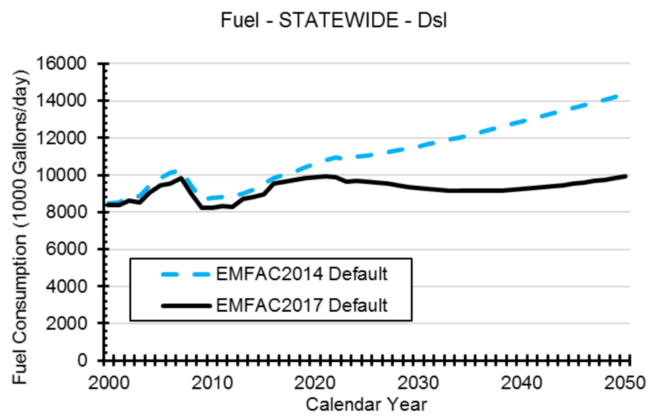


5.1.4. FUEL CONSUMPTIONS

Figure 5.1-6 shows a comparison of gasoline and diesel fuel consumptions between EMFAC2014 and EMFAC2017. As shown, EMFAC2017 has higher estimates of gasoline consumptions in future years mainly due to the update to light duty CO2 emission rates (section 3.1.4) and lower projected ZEV sales as described in section 4.5.4. For diesel, EMFAC2017 has much lower forecasted fuel consumptions in the future mainly in response to Phase 2 fuel efficiency improvements (section 4.3.3.1).

Figure 5.1-6: Comparison of Fuel Consumptions (1000 gallons/day) between EMFAC2014 and EMFAC2017





6. APPENDICES

6.1. VEHICLE CLASS CATEGORIZATION

Table 6.1-1. Summary List of Vehicle Classes

EMFAC2011 Veh & Tech	Description (GVWR = Gross Vehicle Weight Rating, ETW = Equivalent Test Weight)	EMFAC2007 Vehicle
LDA - DSL	Passenger Cars	LDA
LDA - GAS		
LDT1 - DSL	Light-Duty Trucks (GVWR <6000 lbs. and ETW <= 0-3750 lbs)	LDT1
LDT1 - GAS		
LDT2 - DSL	Light-Duty Trucks (GVWR <6000 lbs. and ETW 3751-5750 lbs)	LDT2
LDT2 - GAS		
LHD1 - DSL	Light-Heavy-Duty Trucks (GVWR 8501-10000 lbs)	LHDT1
LHD1 - GAS		
LHD2 - DSL	Light-Heavy-Duty Trucks (GVWR 10001-14000 lbs)	LHDT2
LHD2 - GAS		
MCY - GAS	Motorcycles	MCY
MDV - DSL	Medium-Duty Trucks (GVWR 6000 - 8500 lbs)	MDV
MDV - GAS		
MH - DSL	Motor Homes	MH
MH - GAS		
T6 Ag - DSL	Medium-Heavy Duty Diesel Truck Using the Agricultural provision of Truck and Bus rule	MHDT
T6 CAIRP heavy - DSL	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR>26000 lbs	
T6 CAIRP small - DSL	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR<=26000 lbs	
T6 instate construction heavy - DSL	Medium-Heavy Duty Diesel instate construction Truck with GVWR>26000 lbs	
T6 instate construction small - DSL	Medium-Heavy Duty Diesel instate construction Truck with GVWR<=26000 lbs	
T6 instate heavy - DSL	Medium-Heavy Duty Diesel instate Truck with GVWR>26000 lbs	
T6 instate small - DSL	Medium-Heavy Duty Diesel instate Truck with GVWR<=26000 lbs	
T6 OOS heavy - DSL	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR>26000 lbs	
T6 OOS small - DSL	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR<=26000 lbs	
T6 Public - DSL	Medium-Heavy Duty Diesel Public Fleet Truck	
T6 utility - DSL	Medium-Heavy Duty Diesel Utility Fleet Truck	
T6TS - GAS	Medium-Heavy Duty Gasoline Truck	
T7 Ag - DSL	Heavy-Heavy Duty Diesel Truck Using the Agricultural provision of Truck and Bus rule	HHDT
T7 CAIRP - DSL	Heavy-Heavy Duty Diesel CA International Registration Plan Truck	

EMFAC2011 Veh & Tech	Description (GVWR = Gross Vehicle Weight Rating, ETW = Equivalent Test Weight)	EMFAC2007 Vehicle
T7 CAIRP construction - DSL	Heavy-Heavy Duty Diesel CA International Registration Plan Construction Truck	
T7 NNOOS - DSL	Heavy-Heavy Duty Diesel Non-Neighboring Out-of-state Truck	
T7 NOOS - DSL	Heavy-Heavy Duty Diesel Neighboring Out-of-state Truck	
T7 other port - DSL	Heavy-Heavy Duty Diesel Drayage Truck at Other Facilities	
T7 POAK - DSL	Heavy-Heavy Duty Diesel Drayage Truck in Bay Area	
T7 POLA - DSL	Heavy-Heavy Duty Diesel Drayage Truck near South Coast	
T7 Public - DSL	Heavy-Heavy Duty Diesel Public Fleet Truck	
T7 Single - DSL	Heavy-Heavy Duty Diesel Single Unit Truck	
T7 single construction - DSL	Heavy-Heavy Duty Diesel Single Unit Construction Truck	
T7 SWCV - DSL	Heavy-Heavy Duty Diesel Solid Waste Collection Truck	
T7 SWCV – NG		
T7 tractor - DSL	Heavy-Heavy Duty Diesel Tractor Truck	
T7 tractor construction - DSL	Heavy-Heavy Duty Diesel Tractor Construction Truck	
T7 utility - DSL	Heavy-Heavy Duty Diesel Utility Fleet Truck	
T7IS - GAS	Heavy-Heavy Duty Gasoline Truck	
PTO - DSL	Power Take Off	
SBUS - DSL	School Buses	SBUS
SBUS - GAS		
UBUS - DSL	Urban Buses	UBUS
UBUS - GAS		
UBUS-NG		
Motor Coach - DSL	Motor Coach	OBUS
OBUS - GAS	Other Buses	
All Other Buses - DSL	All Other Buses	

6.2.EXHAUST TECHNOLOGY GROUPS

Table 6.2-1. EMFAC Exhaust Technology Groups

Tech. Group	Model Years Using TG in FRAC arrays	Vehicle Type Using TG in FRAC arrays	Fuel Type	Catalyst	Fuel Delivery	Description
1	1965-1974	LDA-LDT-MDV	GAS	NonCat	Carb	Pre-1975, no secondary air
2	1966-1974	LDA-LDT-MDV	GAS	NonCat	Carb	Pre-1975, with secondary air
3	1975-1979	LDA-LDT-MDV	GAS	NonCat	Carb	1975+
4	1975-1976	LDA-LDT-MDV	GAS	OxCat	Carb	1975-76, with secondary air
5	1975-1979	LDA-LDT-MDV	GAS	OxCat	Carb	1975-79, no secondary air
6	1980-1981	LDA-LDT-MDV	GAS	OxCat	Carb	1980+, no secondary air
7	1977-1984	LDA-LDT-MDV	GAS	OxCat	Carb	1977+, with secondary air
8	1978-1979	LDA-LDT-MDV	GAS	TWC	TBI / Carb	1978-79
9	1981-1984	LDA	GAS	TWC	TBI / Carb	1981-84, 0.7 NOx std.
10	1985-1993	LDA-LDT-MDV	GAS	TWC	TBI / Carb	1985+, 0.7 NOx std.
11	1977-1980	LDA	GAS	TWC	MPFI	1977-80,
12	1981-1985	LDA-LDT-MDV	GAS	TWC	MPFI	1981-85, 0.7 NOx std.
13	1986-1993	LDA-LDT-MDV	GAS	TWC	MPFI	1986+, 0.7 NOx std.
14	1989-1994	LDA-LDT-MDV	GAS	TWC	TBI / Carb	1989+, 0.4 NOx std.
15	1989-1994	LDA-LDT	GAS	TWC	MPFI	1989+, 0.4 NOx std.
16	1980	LDA-LDT-MDV	GAS	TWC	TBI / Carb	1980,
17	1993-1995	LDA-LDT	GAS	TWC	TBI / Carb	1993+, 0.25 HC std.
18	1993-1995	LDA-LDT	GAS	TWC	MPFI	1993+, 0.25 HC std.
19	1996-1999	LDA-LDT	GAS	TWC	TBI / Carb	1996+, 0.25 HC std, OBD2
20	1996-1999	LDA-LDT	GAS	TWC	MPFI	1996+, 0.25 HC std, OBD2
21	1994-1995	LDA-LDT	GAS	Adv.TWC	MPFI	1994-95, TLEV, AFC
22	1996	LDA-LDT	GAS	Adv.TWC	MPFI	1996+, TLEV, OBD2, AFC
23	1997-2003	LDA-LDT-MDV	GAS	Adv.TWC	MPFI	1996+,LEV, OBD2, GCL, CBC, AFC
24	1997-2003	LDA-LDT-MDV	GAS	Adv.TWC	MPFI	1996+,ULEV, OBD2, GCL, CBC, AFC

Tech. Group	Model Years Using TG in FRAC arrays	Vehicle Type Using TG in FRAC arrays	Fuel Type	Catalyst	Fuel Delivery	Description
25	2000-2040	LDA-LDT1	ELE	na	na	ZEV-Pure Electric
26	1996-2000	LDT-MDV	GAS	TWC	MPFI	1996+, 0.7 NOx std., OBD2
27	1996-2000	LDT-MDV	GAS	TWC	TBI / Carb	1996+, OBD2
28	2004-2025	LDA-LDT-MDV	GAS	Adv.TWC	MPFI	2004+, LEV II, OBD2
29	2004-2020	LDA-LDT	GAS	Adv.TWC	MPFI	2004+, ULEV II, OBD2
30	2004-2014	LDA-LDT	GAS	Adv.TWC	MPFI	2004+, SULEV, OBD2
31	2003-2040	LDA-LDT1	GAS	Adv.TWC	MPFI	2004+, PZEV, OBD2
32	2009-2040	LDA-LDT1	GAS	Adv.TWC	MPFI	2004+, Tier2-3 120K //0.055/2.1/0.03, OBD2
33	2007-2040	LDA-LDT	GAS	Adv.TWC	MPFI	2004+, Tier2-4 120K //0.07/2.1/0.04, OBD2
34	2004-2006	MDV	GAS	Adv.TWC	MPFI	2004+, Tier2-8 120K //0.156/4.2/0.2, OBD2
35	2004-2006	LDT2	GAS	Adv.TWC	MPFI	2004+, Tier2-9 120K //0.09/4.2/0.3, OBD2
36	2004-2006	MDV	GAS	Adv.TWC	MPFI	2004+, Tier2-10 120K //0.23/6.4/0.6, OBD2
37	2003-2040	LDA-LDT1	GAS	Adv.TWC	MPFI	2003+, AT PZEV, OBD2
38	2020-2040	LDA-LDT	GAS	Adv.TWC	MPFI	2015+, SULEV 20, OBD2
39	2020-2040	LDA-LDT	GAS	Adv.TWC	MPFI	2015+, ULEV 50, OBD2
40	1965-1979	LDA	GAS	NonCat	Carb	Pre-1980, Mexican veh no secondary air
41	1975-1986	LDA	GAS	OxCat	Carb	1975-76, Mexican veh with secondary air
42	1980-1987	LDA	GAS	TWC	TBI / Carb	1980-87, Mexican veh, 0.7 NOx std.
43	1981-2040	LDA	GAS	TWC	MPFI	1981-2040, Mexican veh, 0.7 NOx std.
44	2015-2025	LDA-LDT	GAS	Adv.TWC	MPFI	2015+, ULEV 70, OBD2
45						Placeholder-do not use-
46	1965-1976	LHDT1	GAS	NonCat	Carb	Pre-1977
47	1977-1983	LHDT1	GAS	OxCat	Carb	1977-83
48	1984-1987	LHDT1	GAS	TWC	Carb	1984-87
49	1988-1990	LHDT1	GAS	TWC	FI	1988-90
50	1991-1995	LHDT1	GAS	TWC	FI	1991-94

Tech. Group	Model Years Using TG in FRAC arrays	Vehicle Type Using TG in FRAC arrays	Fuel Type	Catalyst	Fuel Delivery	Description
51	1995-2001	LHDT1	GAS	TWC	MPFI	1995-01, MDV
52	2002-2003	LHDT1	GAS	TWC	MPFI	2002-03, LEV
53	2004-2008	LHDT1	GAS	Adv.TWC	MPFI	2004-08, ULEV
54	2008-2021	LHDT1	GAS	Adv.TWC	MPFI	2008+, USEPA 2008 stds.
55						Placeholder-do not use-
56						Placeholder-do not use-
57						Placeholder-do not use-
58	2016-2040	LHDT1	GAS	Adv.TWC	MPFI	2016+ LEV 3 ULEV 250
59	2018-2040	LHDT1	GAS	Adv.TWC	MPFI	2018+ LEV 3 SULEV 170
60	1965-1974	LHDT1	DSL			Pre-1975
61	1975-1976	LHDT1	DSL			1975-76
62	1977-1979	LHDT1	DSL			1977-79
63	1980-1983	LHDT1	DSL			1980-83
64	1984-1986	LHDT1	DSL			1984-86
65	1987-1990	LHDT1	DSL			1987-90
66	1991-1993	LHDT1	DSL			1991-93
67	1994-1995	LHDT1	DSL			1994
68	1995-2001	LHDT1	DSL			1995-01, MDV?
69	2002-2003	LHDT1	DSL			2002-03, LEV
70	2004-2009	LHDT1	DSL			2004-09, ULEV
71	2007-2021	LHDT1	DSL			2007+, USEPA 2007 stds.
72						Placeholder-do not use-
73	2016-2040	LHDT1	DSL			2016+ LEV 3 ULEV 250
74	2018-2040	LHDT1	DSL			2018+ LEV 3 SULEV 170
75						Placeholder-do not use-
76	1965-1976	LHDT2	GAS	NonCat	Carb	Pre-1977,
77	1977-1983	LHDT2	GAS	OxCat	Carb	1977-83,

Tech. Group	Model Years Using TG in FRAC arrays	Vehicle Type Using TG in FRAC arrays	Fuel Type	Catalyst	Fuel Delivery	Description
78	1984-1987	LHDT2	GAS	TWC	Carb	1984-87,
79	1988-1990	LHDT2	GAS	TWC	FI	1988-90,
80	1991-1995	LHDT2	GAS	TWC	FI	1991-94,
81	1995-2001	LHDT2	GAS	TWC	MPFI	1995-01, MDV
82	2002-2003	LHDT2	GAS	TWC	MPFI	2002-03, LEV
83	2004-2008	LHDT2	GAS	Adv.TWC	MPFI	2004-08, ULEV
84	2008-2040	LHDT2	GAS	Adv.TWC	MPFI	2008+, USEPA 2008 stds.
85			GAS	Adv.TWC	MPFI	Placeholder-do not use-
86	2016-2040	LHDT2	GAS	Adv.TWC	MPFI	2016+ LEV 3 ULEV 400
87	2018-2040	LHDT2	GAS	Adv.TWC	MPFI	2018+ LEV 3 SULEV 230
88						Placeholder-do not use-
89						Placeholder-do not use-
90	1965-1974	LHDT2	DSL			Pre-1975,
91	1975-1976	LHDT2	DSL			1975-76,
92	1977-1979	LHDT2	DSL			1977-79,
93	1980-1983	LHDT2	DSL			1980-83,
94	1984-1986	LHDT2	DSL			1984-86,
95	1987-1990	LHDT2	DSL			1987-90,
96	1991-1993	LHDT2	DSL			1991-93,
97	1994-1995	LHDT2	DSL			1994
98	1995-2001	LHDT2	DSL			1995-01, MDV
99	2002-2003	LHDT2	DSL			2002-03, LEV
100	2004-2009	LHDT2	DSL			2004-09, ULEV
101	2007-2021	LHDT2	DSL			2007+, USEPA 2007 stds.
102						Placeholder-do not use-
103						Placeholder-do not use-
104	2016-2040	LHDT2	DSL			2016+ LEV 3 ULEV 400

Tech. Group	Model Years Using TG in FRAC arrays	Vehicle Type Using TG in FRAC arrays	Fuel Type	Catalyst	Fuel Delivery	Description
105	2018-2040	LHDT2	DSL			2018+ LEV 3 SULEV 230
106	1965-1976	MHDV	GAS	NonCat	Carb	Pre-1977,
107	1977-1984	MHDV	GAS	OxCat	Carb	1977-83,
108	1984-1987	MHDV	GAS	TWC	Carb	1984-87,
109	1986-1990	MHDV	GAS	TWC	FI	1988-90,
110	1987-1997	MHDV	GAS	TWC	FI	1991-97,
111	1994-2003	MHDV	GAS	TWC	MPFI	1998-03,
112	1998-2004	MHDV	GAS	TWC	MPFI	2004,
113	2004-2040	MHDV	GAS	TWC	MPFI	2005, 1g HC + NOx std.
114	2008-2040	MHDT	GAS	TWC	MPFI	2008+, USEPA 2008 stds.
115						Placeholder-do not use-
116						Placeholder-do not use-
117						Placeholder-do not use-
118						Placeholder-do not use-
119						Placeholder-do not use-
120	1965-1974	MHDT-MH	DSL			Pre-1975,
121	1975-1976	MHDT-MH	DSL			1975-76,
122	1977-1979	MHDT-MH	DSL			1977-79,
123	1980-1983	MHDT-MH	DSL			1980-83,
124	1984-1986	MHDT-MH	DSL			1984-86,
125	1987-1990	MHDT-MH	DSL			1987-90,
126	1991-1993	MHDT-MH	DSL			1991-93,
127	1994-1997	MHDT-MH	DSL			1994-97,
128	1998-1998	MHDT-MH	DSL			1998,
129	1999-2002	MHDT-MH	DSL			1999-02,
130	2003-2006	MHDT-MH	DSL			2003-06, 2g NOx std.
131	2007-2009	MHDT-MH	DSL			2007-09, Transition 2010 stds.

Tech. Group	Model Years Using TG in FRAC arrays	Vehicle Type Using TG in FRAC arrays	Fuel Type	Catalyst	Fuel Delivery	Description
132	2010-2040	MHDT-MH	DSL			2010+, US EPA 2010 stds.
133	2010-2040	MHDT-MH	DSL			2010+, US EPA 2010 stds/OBD
134						Placeholder-do not use-
135						Placeholder-do not use-
136	1965-1976	HHDV-LHV	GAS	NonCat	Carb	Pre-1977,
137	1977-1984	HHDV-LHV	GAS	OxCat	Carb	1977-84,
138	1985-1985	HHDV-LHV	GAS	TWC	Carb	1985
139	1986-1986	HHDV-LHV	GAS	TWC	FI	1986
140	1987-1993	HHDV-LHV	GAS	TWC	FI	1987-93,
141	1994-1997	HHDV-LHV	GAS	TWC	MPFI	1994-97,
142	1998-2003	HHDV-LHV	GAS	TWC	MPFI	1998-03,
143	2004-2040	HHDV-LHV	GAS	TWC	MPFI	2004-06,
144			GAS	TWC	MPFI	2007+ USEPAs std Placeholder-do not use-
145						Placeholder-do not use-
146						Placeholder-do not use-
147						Placeholder-do not use-
148						Placeholder-do not use-
149						Placeholder-do not use-
150	1965-1974	HHDV-LHV	DSL			Pre-1975, CA stds.
151	1975-1976	HHDV-LHV	DSL			1975-76, CA Stds.
152	1977-1979	HHDV-LHV	DSL			1977-79, CA Stds.
153	1980-1983	HHDV-LHV	DSL			1980-83, CA Stds.
154	1984-1986	HHDV-LHV	DSL			1984-86, CA Stds.
155	1987-1990	HHDV-LHV	DSL			1987-90, CA Stds.
156	1991-1993	HHDV-LHV	DSL			1991-93, CA Stds.
157	1994-1997	HHDV-LHV	DSL			1994-97, CA Stds.

Tech. Group	Model Years Using TG in FRAC arrays	Vehicle Type Using TG in FRAC arrays	Fuel Type	Catalyst	Fuel Delivery	Description
158	1998-1998	HHDV-LHV	DSL			1998, CA Stds.
159	1999-2002	HHDV-LHV	DSL			1999-02, CA Stds.
160	2003-2006	HHDV-LHV	DSL			2003-06, CA 2g NOx Stds.
161	2007-2009	HHDV-LHV	DSL			2007-2009, USEPA 2007 stds.
162	2010+	HHDV-LHV	DSL			2010+, USEPA 2007 stds.
163	2010+	HHDV-LHV	DSL			2010+ , USEPA 2007 stds. W/OBD2
164						Placeholder-do not use-
165						Placeholder-do not use-
166						Placeholder-do not use-
167						Placeholder-do not use-
168						Placeholder-do not use-
169						Placeholder-do not use-
170	1965-1974	LDA-LDT-MDV	DSL			Pre-1975,
171	1975-1979	LDA-LDT-MDV	DSL			1975-79,
172	1980-1980	LDA-LDT-MDV	DSL			1980,
173	1981-1981	LDA-LDT-MDV	DSL			1981,
174	1982-1982	LDA-LDT-MDV	DSL			1982,
175	1983-1983	LDA-LDT-MDV	DSL			1983,
176	1984-1992	LDA-LDT-MDV	DSL			1984-92,
177	1993-2003	LDA-LDT-MDV	DSL			1993+,
178	2007-2025	LDA LT3	DSL	DPF SCR		2008+, LEV 160 DSL, OBD2
179	2007-2025	LDA LT3	DSL	DPF SCR		2008+, ULEV 125 DSL, OBD2
180	2020-2040	LDA LT3	DSL	DPF SCR		2020+, SULEV 30 DSL, OBD2
181			DSL			Placeholder - do not use -
182			DSL			Placeholder - do not use -
183			DSL			Placeholder - do not use -
184			DSL			Placeholder - do not use -

Tech. Group	Model Years Using TG in FRAC arrays	Vehicle Type Using TG in FRAC arrays	Fuel Type	Catalyst	Fuel Delivery	Description
185			DSL			Placeholder - do not use -
186			DSL			Placeholder - do not use -
187			DSL			Placeholder - do not use -
188			DSL			Placeholder - do not use -
189			DSL			Placeholder - do not use -
190			DSL			Placeholder - do not use -
191			DSL			Placeholder - do not use -
192			DSL			Placeholder - do not use -
193			DSL			Placeholder - do not use -
194			DSL			Placeholder - do not use -
195						Placeholder - do not use -
196						Placeholder - do not use -
197						Placeholder - do not use -
198						Placeholder - do not use -
199						Placeholder - do not use -
200	1965-1973	HHDV-LHV	DSL			Pre-1974, Federal Stds.
201	1974-1978	HHDV-LHV	DSL			1974-78, Federal Stds.
202	1979-1983	HHDV-LHV	DSL			1979-83, Federal Stds.
203	1984-1987	HHDV-LHV	DSL			1984-87, Federal Stds.
204	1988-1990	HHDV-LHV	DSL			1988-90, Federal Stds.
205	1991-1993	HHDV-LHV	DSL			1991-93, Federal Stds.
206	1994-1997	HHDV-LHV	DSL			1994-97, Federal Stds.
207	1998-1998	HHDV-LHV	DSL			1998, Federal Stds.
208	1999-2003	HHDV-LHV	DSL			1999-02, Federal Stds.
209	2003-2009	HHDV-LHV	DSL			2003-06, Federal Stds.
210	2007-2009	HHDV-LHV	DSL			2007-2009, USEPA 2007 stds.
211	2010+	HHDV-LHV	DSL			2010+, USEPA 2007 stds.

Tech. Group	Model Years Using TG in FRAC arrays	Vehicle Type Using TG in FRAC arrays	Fuel Type	Catalyst	Fuel Delivery	Description
212						Placeholder - do not use -
213						Placeholder - do not use -
214						Placeholder - do not use -
215						Placeholder - do not use -
216	1965-1986	UB	DSL			Pre-87,
217	1987-1990	UB	DSL			1987-90,
218	1991-1993	UB	DSL			1991-93,
219	1994-1995	UB	DSL			1994-95,
220	1996-1998	UB	DSL			1996-98,
221	1999-2002	UB	DSL			1999-02,
222	2003-2003	UB	DSL			2003,
223	2004-2006	UB	DSL			2004-06,
224	2007-2040	UB	DSL			2007,
225	2008-2040	UB	DSL			2008+, ZEV or ZEBS
226						Placeholder - do not use -
227						Placeholder - do not use -
228	1965-1976	SBUS	GAS	NonCat	Carb	Pre-77,
229	1977-1983	SBUS	GAS	OxCat	TBI / Carb	1977-83,
230	1984-1987	SBUS	GAS	TWC	FI	1984-87,
231	1988-1990	SBUS	GAS	TWC	FI	1988-90,
232	1991-1997	SBUS	GAS	TWC	FI	1991-97,
233	1998-2003	SBUS	GAS	TWC	MPFI	1998-03,
234	2004-2004	SBUS	GAS	TWC	MPFI	2004,
235	2005-2008	SBUS	GAS	TWC	MPFI	2005,1g HC+NOx Stds.
236	2008-2040	SBUS	GAS	TWC	MPFI	2008+, USEPAs Stds.
237						Placeholder - do not use -
238						Placeholder - do not use -

Tech. Group	Model Years Using TG in FRAC arrays	Vehicle Type Using TG in FRAC arrays	Fuel Type	Catalyst	Fuel Delivery	Description
239						Placeholder - do not use -
240	1965-1974	SBUS	DSL			Pre-75,
241	1975-1976	SBUS	DSL			1975-76,
242	1977-1979	SBUS	DSL			1977-79,
243	1980-1983	SBUS	DSL			1980-83,
244	1984-1986	SBUS	DSL			1984-86,
245	1987-1990	SBUS	DSL			1987-90,
246	1991-1993	SBUS	DSL			1991-93,
247	1994-1997	SBUS	DSL			1994-97,
248	1998-1998	SBUS	DSL			1998,
249	1999-2003	SBUS	DSL			1999-02,
250	2003-2009	SBUS	DSL			2003-06, 2g NOx Std
251	2007-2040	SBUS	DSL			2007+, USEPA Std.
252						Placeholder - do not use -
253						Placeholder - do not use -
254						Placeholder - do not use -
255						Placeholder - do not use -
256						Placeholder - do not use -
257						Placeholder - do not use -
258						Placeholder - do not use -
259						Placeholder - do not use -
260	1965-1977	MCY	GAS	NonCat	2-Stroke	All, 6g evap Std.
261	1965-1977	MCY	GAS	NonCat	Carb	Pre-1978, 6g evap Std.
262	1978-1979	MCY	GAS	NonCat	Carb	1978-79, 6g evap Std.
263	1980-1981	MCY	GAS	NonCat	Carb	1980-81, 6g evap Std.
264	1982-1984	MCY	GAS	NonCat	Carb	1982-84, 6g evap Std.
265	1985-1987	MCY	GAS	NonCat	Carb	1985-87, 2g evap Std.

Tech. Group	Model Years Using TG in FRAC arrays	Vehicle Type Using TG in FRAC arrays	Fuel Type	Catalyst	Fuel Delivery	Description
266	1988-2003	MCY	GAS	NonCat	Carb	1988-03, 2g evap Std.
267	1994-2003	MCY	GAS	NonCat	FI	1988-03, 2g evap Std.
268	1995-2003	MCY	GAS	OxCat	Carb	1988-03, 2g evap Std.
269	1994-2003	MCY	GAS	TWC	FI	1988-03, 2g evap Std.
270	2004-2007	MCY	GAS	NonCat	Carb	2003-08, 2g evap Std.
271	2004-2007	MCY	GAS	NonCat	FI	2003-08, 2g evap Std.
272	2004-2007	MCY	GAS	OxCat	Carb	2003-08, 2g evap Std.
273	2004-2007	MCY	GAS	TWC	FI	03-08 MCY FI/cat/2g evap
274	2008-2040	MCY	GAS	NonCat	Carb	2008+, 2 evap Std.
275	2008-2040	MCY	GAS	NonCat	FI	2008+, 2 evap Std.
276	2008-2040	MCY	GAS	OxCat	Carb	2008+, 2 evap Std.
277	2008-2040	MCY	GAS	TWC	FI	2008+, 2 evap Std.
278						Placeholder - do not use -
279						Placeholder - do not use -
280						Placeholder - do not use -

6.3.NATURAL GAS HEAVY DUTY TRUCK PENETRATION

Table 6.3-1. Heavy-duty natural gas penetration by EMFAC vehicle category and air district.

Vehicle Category	Air District Name	Prediction Class	Slope	Intercept
T6 Public	BAY AREA AQMD	Flat8Yr	0	0.027
T6 Public	IMPERIAL COUNTY APCD	Flat8Yr	0	0.210
T6 Public	SACRAMENTO METROPOLITAN AQMD	Flat8Yr	0	0.048
T6 Public	SAN DIEGO COUNTY APCD	Flat8Yr	0	0.009
T6 Public	SAN JOAQUIN VALLEY UNIFIED APCD	Flat8Yr	0	0.052
T6 Public	SOUTH COAST AQMD	Flat8Yr	0	0.086
T6 CAIRP Heavy	SOUTH COAST AQMD	Flat8Yr	0	0.002
T6 Instate Construction Small	BAY AREA AQMD	Flat8Yr	0	0.004
T6 Instate Construction Small	SOUTH COAST AQMD	Flat8Yr	0	0.003
T6 Instate Construction Heavy	BAY AREA AQMD	Flat8Yr	0	0.005
T6 Instate Construction Heavy	MONTEREY BAY UNIFIED APCD	Flat8Yr	0	0.029
T6 Instate Construction Heavy	SACRAMENTO METROPOLITAN AQMD	Flat8Yr	0	0.017
T6 Instate Construction Heavy	SOUTH COAST AQMD	Flat8Yr	0	0.021
T6 Instate Small	BAY AREA AQMD	Flat8Yr	0	0.005
T6 Instate Small	CALAVERAS COUNTY APCD	Flat8Yr	0	0.044
T6 Instate Small	LASSEN COUNTY APCD	Flat8Yr	0	0.100
T6 Instate Small	SAN DIEGO COUNTY APCD	Flat8Yr	0	0.002
T6 Instate Small	SANTA BARBARA COUNTY APCD	Flat8Yr	0	0.004
T6 Instate Small	SOUTH COAST AQMD	Flat8Yr	0	0.004
T6 Instate Heavy	AMADOR COUNTY APCD	Flat8Yr	0	0.040
T6 Instate Heavy	ANTELOPE VALLEY AQMD	Flat8Yr	0	0.067
T6 Instate Heavy	BAY AREA AQMD	Flat8Yr	0	0.008
T6 Instate Heavy	MONTEREY BAY UNIFIED APCD	Flat8Yr	0	0.021
T6 Instate Heavy	NORTHERN SIERRA AQMD	Flat8Yr	0	0.050
T6 Instate Heavy	SACRAMENTO METROPOLITAN AQMD	Flat8Yr	0	0.016
T6 Instate Heavy	SAN JOAQUIN VALLEY UNIFIED APCD	Flat8Yr	0	0.001
T6 Instate Heavy	SANTA BARBARA COUNTY APCD	Flat8Yr	0	0.018
T6 Instate Heavy	SOUTH COAST AQMD	Flat8Yr	0	0.023
T6 Utility	AMADOR COUNTY APCD	Flat8Yr	0	0.200
T6 Utility	BAY AREA AQMD	Flat8Yr	0	0.020
T6 Utility	SACRAMENTO METROPOLITAN AQMD	Flat8Yr		0.006
T6 Utility	SAN JOAQUIN VALLEY UNIFIED APCD	Flat8Yr	0.00	0.005
T6 Utility	SOUTH COAST AQMD	Flat8Yr	0.00	0.014
T7 Public	BAY AREA AQMD	Flat8Yr	0.00	0.007
T7 Public	IMPERIAL COUNTY APCD	Flat8Yr	0.00	0.025
T7 Public	SACRAMENTO METROPOLITAN AQMD	Flat8Yr	0.00	0.019
T7 Public	SAN DIEGO COUNTY APCD	Flat8Yr	0.00	0.004

Vehicle Category	Air District Name	Prediction Class	Slope	Intercept
T7 Public	SAN JOAQUIN VALLEY UNIFIED APCD	Flat8Yr	0.00	0.067
T7 Public	SOUTH COAST AQMD	Linear Growth	0.00	-66.651
T7 Public	YOLO/SOLANO AQMD	Flat8Yr	0.00	0.011
T7 CAIRP	BAY AREA AQMD	Flat8Yr	0.00	0.000
T7 CAIRP	SOUTH COAST AQMD	Flat8Yr	0.00	0.005
T7 CAIRP Construction	SOUTH COAST AQMD	Flat8Yr	0.00	0.003
T7 POAK	BAY AREA AQMD	Flat8Yr	0.00	0.005
T7 POLA	ANTELOPE VALLEY AQMD	Flat8Yr	0.00	0.200
T7 POLA	BAY AREA AQMD	Flat8Yr	0.00	0.183
T7 POLA	IMPERIAL COUNTY APCD	Flat8Yr	0.00	0.225
T7 POLA	MOJAVE DESERT AQMD	Flat8Yr	0.00	0.111
T7 POLA	SOUTH COAST AQMD	Flat8Yr	0.00	0.050
T7 Single	ANTELOPE VALLEY AQMD	Flat8Yr	0.00	0.018
T7 Single	BAY AREA AQMD	Flat8Yr	0.00	0.038
T7 Single	BUTTE COUNTY AQMD	Flat8Yr	0.00	0.022
T7 Single	EL DORADO COUNTY APCD	Flat8Yr	0.00	0.025
T7 Single	MENDOCINO COUNTY AQMD	Flat8Yr	0.00	0.030
T7 Single	MOJAVE DESERT AQMD	Flat5Yr	0.00	0.043
T7 Single	MONTEREY BAY UNIFIED APCD	Flat8Yr	0.00	0.042
T7 Single	NORTH COAST UNIFIED AQMD	Flat5Yr	0.00	0.035
T7 Single	PLACER COUNTY APCD	Flat8Yr	0.00	0.015
T7 Single	SACRAMENTO METROPOLITAN AQMD	Flat8Yr	0.00	0.046
T7 Single	SAN DIEGO COUNTY APCD	Flat8Yr	0.00	0.042
T7 Single	SAN JOAQUIN VALLEY UNIFIED APCD	Flat8Yr	0.00	0.042
T7 Single	SAN LUIS OBISPO COUNTY APCD	Flat5Yr	0.00	0.038
T7 Single	SANTA BARBARA COUNTY APCD	Flat5Yr	0.00	0.055
T7 Single	SHASTA COUNTY AQMD	Flat5Yr	0.00	0.044
T7 Single	SOUTH COAST AQMD	Flat8Yr	0.00	0.044
T7 Single	VENTURA COUNTY APCD	Flat8Yr	0.00	0.039
T7 Single	YOLO/SOLANO AQMD	Flat5Yr	0.00	0.034
T7 Single Construction	BAY AREA AQMD	Flat8Yr	0.00	0.043
T7 Single Construction	MOJAVE DESERT AQMD	Flat8Yr	0.00	0.025
T7 Single Construction	SAN DIEGO COUNTY APCD	Flat8Yr	0.03	0.047
T7 Single Construction	SAN JOAQUIN VALLEY UNIFIED APCD	Flat8Yr	0.00	0.034
T7 Single Construction	SOUTH COAST AQMD	Flat8Yr	0.00	0.048
T7 Tractor	BAY AREA AQMD	Flat8Yr	0.00	0.019
T7 Tractor	BUTTE COUNTY AQMD	Flat8Yr	0.00	0.008
T7 Tractor	FEATHER RIVER AQMD	Flat8Yr	0.00	0.009
T7 Tractor	IMPERIAL COUNTY APCD	Flat8Yr	0.00	0.024
T7 Tractor	KERN COUNTY APCD	Flat8Yr	0.00	0.007

Vehicle Category	Air District Name	Prediction Class	Slope	Intercept
T7 Tractor	MENDOCINO COUNTY AQMD	Flat8Yr	0.00	0.014
T7 Tractor	MOJAVE DESERT AQMD	Flat8Yr	0.00	0.017
T7 Tractor	MONTEREY BAY UNIFIED APCD	Flat8Yr	0.00	0.009
T7 Tractor	PLACER COUNTY APCD	Flat8Yr	0.00	0.009
T7 Tractor	SACRAMENTO METROPOLITAN AQMD	Flat8Yr	0.00	0.026
T7 Tractor	SAN DIEGO COUNTY APCD	Flat8Yr	0.00	0.019
T7 Tractor	SAN JOAQUIN VALLEY UNIFIED APCD	Flat8Yr	0.00	0.021
T7 Tractor	SAN LUIS OBISPO COUNTY APCD	Flat8Yr	0.00	0.013
T7 Tractor	SANTA BARBARA COUNTY APCD	Flat8Yr	0.00	0.013
T7 Tractor	SHASTA COUNTY AQMD	Flat8Yr	0.00	0.021
T7 Tractor	SISKIYOU COUNTY APCD	Flat8Yr	0.00	0.014
T7 Tractor	SOUTH COAST AQMD	Flat8Yr	0.00	0.021
T7 Tractor	TEHAMA COUNTY APCD	Flat8Yr	0.00	0.014
T7 Tractor	VENTURA COUNTY APCD	Flat8Yr	0.00	0.007
T7 Tractor	YOLO/SOLANO AQMD	Flat8Yr	0.00	0.014
T7 Tractor Construction	BAY AREA AQMD	Flat8Yr	0.00	0.022
T7 Tractor Construction	SAN DIEGO COUNTY APCD	Flat8Yr	0.00	0.028
T7 Tractor Construction	SAN JOAQUIN VALLEY UNIFIED APCD	Flat8Yr	0.00	0.014
T7 Tractor Construction	SOUTH COAST AQMD	Flat8Yr	0.00	0.024
SBUS	ANTELOPE VALLEY AQMD	Flat8Yr	0.00	0.268
SBUS	BAY AREA AQMD	Flat8Yr	0.00	0.091
SBUS	SAN DIEGO COUNTY APCD	Flat8Yr	0.00	0.004
SBUS	SAN JOAQUIN VALLEY UNIFIED APCD	Flat8Yr	0.00	0.102
SBUS	SANTA BARBARA COUNTY APCD	Flat8Yr	0.00	0.280
SBUS	SOUTH COAST AQMD	Flat8Yr	0.00	0.833
SBUS	VENTURA COUNTY APCD	Flat8Yr	0.00	0.040
All Other Buses	BAY AREA AQMD	Flat8Yr	0.00	0.003
All Other Buses	SACRAMENTO METROPOLITAN AQMD	Flat8Yr	0.00	0.050
All Other Buses	SAN DIEGO COUNTY APCD	Flat8Yr	0.00	0.184
All Other Buses	SAN LUIS OBISPO COUNTY APCD	Flat8Yr	0.00	0.145
All Other Buses	SOUTH COAST AQMD	Flat8Yr	0.00	0.130
All Other Buses	YOLO/SOLANO AQMD	Flat8Yr	0.00	0.160

6.4. LA 92 CYCLE

Table 6.4-1: LA92 Comparison for Phases 1 and 3

Time (Sec)	LA 92 Original (MPH)	LA 92 Modified (MPH)	Time (Sec)	LA 92 Original (MPH)	LA 92 Modified (MPH)	Time (Sec)	LA 92 Original (MPH)	LA 92 Modified (MPH)
1	0	0	101	26.9	0	201	39.9	2.7
2	0	0	102	26.5	0	202	40.7	0.4
3	0	0	103	25.7	0	203	40.3	0.4
4	0	0	104	21.9	0	204	41.1	2.7
5	0	0	105	16.5	0	205	41.1	3.8
6	0	0	106	10	0	206	40.7	3.8
7	0	0	107	4.6	0	207	31.9	1.5
8	0	0	108	1.5	0.4	208	23.9	0
9	0	0	109	0.4	1.2	209	15.9	0
10	0	0	110	0	1.9	210	7.9	0
11	0	0	111	0	3.8	211	2.7	0
12	0	0	112	0	7.7	212	0.4	0
13	0	0	113	0	11.5	213	0.4	0
14	0	0	114	0	14.6	214	2.7	0
15	0	0	115	0	18	215	3.8	0
16	0	0	116	0	21.5	216	3.8	0
17	0	0	117	0	25	217	1.5	0
18	0	0	118	0.4	28.4	218	0	0
19	0	0	119	1.2	30.7	219	0	0
20	0	0	120	1.9	31.9	220	0	0
21	0	1.2	121	3.8	32.3	221	0	0
22	0	4.2	122	7.7	32.3	222	0	0
23	0	7.3	123	11.5	31.9	223	0	0
24	0	8.8	124	14.6	30.3	224	0	0
25	0	10.8	125	18	28	225	0	0
26	0	12.3	126	21.5	24.2	226	0	0
27	0	13.1	127	25	20	227	0	0
28	0	12.3	128	28.4	16.1	228	0	0
29	0	12.3	129	30.7	11.5	229	0	0
30	0	11.5	130	31.9	8.1	230	0	0
31	1.2	11.5	131	32.3	5	231	0	0
32	4.2	11.1	132	32.3	3.5	232	0	0
33	7.3	11.1	133	31.9	1.9	233	0	0
34	8.8	11.1	134	30.3	0	234	0	0
35	10.8	13.1	135	28	0	235	0	0
36	12.3	15	136	24.2	0	236	0	0

Time (Sec)	LA 92 Original (MPH)	LA 92 Modified (MPH)	Time (Sec)	LA 92 Original (MPH)	LA 92 Modified (MPH)	Time (Sec)	LA 92 Original (MPH)	LA 92 Modified (MPH)
37	13.1	16.9	137	20	0	237	0	0
38	12.3	16.9	138	16.1	0	238	0	1.5
39	12.3	16.1	139	11.5	0	239	0	5
40	11.5	15.7	140	8.1	0	240	0	8.8
41	11.5	15.4	141	5	0	241	0	11.5
42	11.1	15	142	3.5	0	242	0	14.2
43	11.1	13.8	143	1.9	1.5	243	0	15.4
44	11.1	10.8	144	0	6.9	244	0	16.1
45	13.1	8.4	145	0	12.7	245	0	16.1
46	15	6.1	146	0	16.5	246	0	16.9
47	16.9	4.2	147	0	20	247	0	16.5
48	16.9	3.5	148	0	23	248	1.5	16.9
49	16.1	3.5	149	0	25.7	249	5	18
50	15.7	1.5	150	0	28	250	8.8	19.2
51	15.4	0	151	0	30.7	251	11.5	20.4
52	15	0	152	0	32.6	252	14.2	20.4
53	13.8	0	153	1.5	34.2	253	15.4	21.1
54	10.8	0	154	6.9	35.3	254	16.1	21.1
55	8.4	0	155	12.7	36.9	255	16.1	22.3
56	6.1	0	156	16.5	36.9	256	16.9	23
57	4.2	0	157	20	37.2	257	16.5	23.8
58	3.5	0	158	23	37.6	258	16.9	24.2
59	3.5	0	159	25.7	37.6	259	18	24.6
60	1.5	0	160	28	37.6	260	19.2	25
61	0	0	161	30.7	37.2	261	20.4	25.7
62	0	0	162	32.6	37.2	262	20.4	25.7
63	0	1.2	163	34.2	36.9	263	21.1	26.5
64	0	3.5	164	35.3	36.5	264	21.1	27.6
65	0	7.7	165	36.9	36.5	265	22.3	28.4
66	0	11.1	166	36.9	34.9	266	23	29.2
67	0	13.8	167	37.2	33.4	267	23.8	30.3
68	0	16.5	168	37.6	31.9	268	24.2	31.1
69	0	18.4	169	37.6	29.2	269	24.6	31.1
70	0	20.4	170	37.6	25	270	25	30.7
71	0	20.7	171	37.2	25	271	25.7	31.1
72	0	19.6	172	37.2	26.1	272	25.7	29.6
73	1.2	17.3	173	36.9	27.6	273	26.5	29.2
74	3.5	12.3	174	36.5	29.2	274	27.6	29.2
75	7.7	8.1	175	36.5	31.1	275	28.4	28.8
76	11.1	6.1	176	34.9	32.3	276	29.2	28

Time (Sec)	LA 92 Original (MPH)	LA 92 Modified (MPH)	Time (Sec)	LA 92 Original (MPH)	LA 92 Modified (MPH)	Time (Sec)	LA 92 Original (MPH)	LA 92 Modified (MPH)
77	13.8	9.6	177	33.4	34.2	277	30.3	23
78	16.5	12.7	178	31.9	34.9	278	31.1	21.1
79	18.4	15.7	179	29.2	35.7	279	31.1	21.5
80	20.4	18	180	25	36.5	280	30.7	20.7
81	20.7	20.4	181	25	36.9	281	31.1	20.7
82	19.6	21.9	182	26.1	36.9	282	29.6	19.6
83	17.3	23.4	183	27.6	37.2	283	29.2	16.5
84	12.3	23.8	184	29.2	37.6	284	29.2	13.1
85	8.1	24.6	185	31.1	37.2	285	28.8	9.6
86	6.1	25	186	32.3	37.6	286	28	7.3
87	9.6	26.1	187	34.2	38	287	23	3.8
88	12.7	26.1	188	34.9	38.4	288	21.1	0.8
89	15.7	26.9	189	35.7	39.2	289	21.5	0
90	18	26.9	190	36.5	39.6	290	20.7	0
91	20.4	26.9	191	36.9	39.9	291	20.7	0
92	21.9	26.5	192	36.9	40.7	292	19.6	0
93	23.4	25.7	193	37.2	40.3	293	16.5	0
94	23.8	21.9	194	37.6	41.1	294	13.1	0
95	24.6	16.5	195	37.2	41.1	295	9.6	0
96	25	10	196	37.6	40.7	296	7.3	0
97	26.1	4.6	197	38	31.9	297	3.8	0
98	26.1	1.5	198	38.4	23.9	298	0.8	0
99	26.9	0.4	199	39.2	15.9	299	0	0
100	26.9	0	200	39.6	7.9	300	0	0

6.5. EMISSION TEST DATA FROM CARB TRUCK AND BUS SURVEILLANCE PROGRAM

Table 6.5-1. Emission Test Data from CARB Truck and Bus Surveillance Program

Veh ID	Eng Make	Eng MY	Odometer (mi)	Test Cycle	HC (g/mi)	CO (g/mi)	NO_X (g/mi)	PM (mg/mi)	CO_2 (g/mi)
P-1	Navistar	2014	132,796	UDDS	0.008	0.023	0.36	8.99	2,121
				Creep	0.387	5.343	9.32	7.91	5,094
				Near Dock	0.078	0.224	2.47	6.67	2,261
				Local	0.038	0.482	0.81	4.12	2,178
				Cruise	0.003	0.023	0.14	5.47	1,374
				HS Cruise	0.003	0.001	0.07	11.3	1,636
L-1	Cummins	2013	66,145	UDDS	0.022	0.014	9.65	n.r.*	2,098
				Creep	0.309	0.060	22.3	n.r.	5,762
				Near Dock	0.137	0.033	10.7	n.r.	2,511
				Local	0.082	0.077	9.42	n.r.	2,383
				Cruise	0.013	0.024	1.95	n.r.	1,367
				HS Cruise	0.009	0.032	1.57	n.r.	1,609
O-3	Cummins	2014	112,134	UDDS	0.020	0.014	4.73	10.6	2,317
				Creep	0.263	0.001	11.5	6.57	8,796
				Near Dock	0.056	0.001	3.65	9.86	3,411
				Local	0.038	0.002	2.68	6.26	2,825
				Cruise	0.010	0.011	1.08	5.70	1,358
				HS Cruise	0.007	0.023	0.83	41.0	1,564
K-2	Paccar	2013	180,598	UDDS	0.008	0.082	2.65	8.64	2,005
				Creep	0.627	6.808	21.9	8.51	4,378
				Near Dock	0.225	0.859	13.9	2.82	2,148
				Local	0.102	0.320	7.87	2.05	2,028
				Cruise	0.005	0.012	0.47	12.3	1,365
K-3	Paccar	2013	248,095	UDDS	0.007	0.394	0.55	3.72	2,096
				Creep	0.238	8.346	13.63	3.96	4,116
				Near Dock	0.050	1.036	2.87	2.40	2,379
				Local	0.022	0.321	1.61	2.52	2,122
				Cruise	0.004	0.037	0.22	6.68	1,367
I-3	Cummins	2012	632,377	UDDS	0.094	0.072	5.54	5.52	2,554
				Creep	0.066	0.006	17.9	5.39	9,434
				Near Dock	0.023	0.038	2.36	1.73	3,909
				Local	0.024	0.057	1.63	0.80	3,279

Veh ID	Eng Make	Eng MY	Odometer (mi)	Test Cycle	HC (g/mi)	CO (g/mi)	NO_X (g/mi)	PM (mg/mi)	CO_2 (g/mi)
				Cruise	0.007	0.051	1.50	1.83	1,485
				HS Cruise	0.039	0.091	3.53	9.91	1,823
O-1	Cummins	2014	144,194	UDDS	0.020	0.028	3.28	12.9	2,170
				Creep	0.413	0.488	8.42	4.54	9,864
				Near Dock	0.055	0.084	1.68	7.99	3,622
				Local	0.043	0.156	1.66	5.44	3,059
				Cruise	0.010	0.001	0.65	3.96	1,309
				HS Cruise	0.008	0.013	0.24	67.8	1,469
O-2	Cummins	2014	185,078	UDDS	0.019	0.011	3.96	6.61	2,114
				Creep	0.303	n.r.	14.2	4.92	8,969
				Near Dock	0.055	0.001	3.11	3.77	3,347
				Local	0.094	0.165	6.50	2.68	2,577
				Cruise	0.018	0.056	2.00	2.60	1,330
				HS Cruise	0.014	0.033	1.59	27.6	1,464
M-2	Volvo	2014	370,454	UDDS	0.046	0.494	9.63	1.97	2,025
				Creep	0.332	11.541	43.8	0.99	3,792
				Near Dock	0.139	1.686	15.4	0.89	1,994
				Local	0.127	1.032	15.6	2.36	2,092
M-1	Volvo	2014	187,291	UDDS	0.009	0.439	4.02	4.06	2,120
				Creep	0.193	8.693	38.6	2.75	4,319
				Near Dock	0.044	1.364	12.3	1.30	2,297
				Local	0.029	0.520	10.6	1.50	2,173
				Cruise	0.019	0.094	1.23	4.81	1,358
				HS Cruise	0.011	0.087	1.32	9.51	1,519
B-2	Cummins	2010	456,350	UDDS	0.020	0.169	5.45	0.81	2,281
				Creep	0.423	0.438	26.4	43.1	10,641
				Near Dock	0.050	0.391	11.8	2.35	2,880
				Local	0.096	0.105	10.0	17.0	2,953
				Cruise	0.008	0.106	2.68	0.82	1,344
				HS Cruise	0.008	0.115	3.55	0.65	1,491
N-2	Detroit Diesel	2014	177,394	UDDS	0.007	0.034	1.76	15.3	2,169
				Creep	0.089	0.622	13.0	n.r.	4,504
				Near Dock	0.026	0.100	4.07	4.19	2,292
				Local	0.012	0.034	1.92	7.17	2,103
				Cruise	0.004	0.006	0.36	4.78	1,337
				HS Cruise	0.002	0.003	0.32	8.51	1,511

Veh ID	Eng Make	Eng MY	Odometer (mi)	Test Cycle	HC (g/mi)	CO (g/mi)	NO_X (g/mi)	PM (mg/mi)	CO_2 (g/mi)
C-2	Detroit Diesel	2010	464,703	UDDS	0.010	0.052	1.78	0.81	2,110
				Creep	0.063	1.012	8.97	0.37	3,887
				Near Dock	0.027	0.273	3.19	2.00	2,074
				Local	0.012	0.085	1.57	1.26	2,072
				Cruise	0.004	0.077	1.24	8.91	1,386
				HS Cruise	0.003	0.012	1.12	19.0	1,524
B-3	Cummins	2010	688,950	UDDS	0.013	0.026	0.76	2.39	2,439
				Creep	0.126	0.004	12.4	5.15	10,270
				Near Dock	0.078	0.056	2.25	61.5	4,252
				Local	0.025	0.019	0.93	2.71	3,038
				Cruise	0.010	0.018	0.65	0.86	1,322
K-1	Paccar	2013	144,683	UDDS	0.008	0.509	0.97	0.53	1,978
				Creep	0.521	7.226	10.5	0.49	4,911
				Near Dock	0.078	1.244	4.12	0.20	2,127
				Local	0.018	0.398	1.38	0.87	2,074
				Cruise	0.005	0.025	0.17	1.33	1,261
L-1	Cummins	2013	66,145	UDDS	0.017	0.003	4.94	1.68	2,048
				Creep	0.270	0.518	11.4	n.r.	7,908
				Near Dock	0.079	0.013	4.13	2.14	2,949
				Local	0.059	0.003	5.25	3.06	2,303
				Cruise	0.010	0.003	1.27	2.41	1,226
				HS Cruise	0.009	0.016	0.81	18.9	1,409
N-1	Detroit Diesel	2014	240,785	UDDS	0.009	0.032	1.58	1.18	2,019
				Creep	0.132	2.515	18.2	2.18	3,975
				Near Dock	0.042	0.296	6.51	1.79	2,029
				Local	0.023	0.053	3.42	0.72	1,928
				Cruise	0.008	0.031	0.48	0.63	1,202
				HS Cruise	0.004	0.027	0.63	3.63	1,427
F-1	Cummins	2011	169,036	UDDS	0.011	0.066	7.51	2.48	2,114
				Creep	0.043	0.010	14.0	3.45	7,305
				Near Dock	0.022	0.057	9.30	0.83	2,620
				Local	0.068	0.080	9.34	2.30	2,418
				Cruise	0.018	0.096	2.50	22.6	1,454
				HS Cruise	0.020	0.163	3.04	61.7	1,694

Veh ID	Eng Make	Eng MY	Odometer (mi)	Test Cycle	HC (g/mi)	CO (g/mi)	NO_X (g/mi)	PM (mg/mi)	CO_2 (g/mi)
F-2	Cummins	2011	372,221	UDDS	0.022	0.019	8.14	1.42	2,050
				Creep	0.086	0.090	22.4	6.64	6,635
				Near Dock	0.040	0.059	14.4	0.70	2,666
				Local	0.028	0.032	14.1	0.85	2,206
				Cruise	0.009	0.018	3.25	0.50	1,256
				HS Cruise	0.008	0.037	1.90	1.33	1,430
F-3	Cummins	2011	593,321	UDDS	0.013	0.034	9.02	1.26	2,079
				Creep	0.131	0.014	20.1	2.97	6,450
				Near Dock	0.047	0.009	13.0	2.24	2,729
				Local	0.034	0.006	11.9	0.45	2,319
				Cruise	0.009	0.047	3.02	0.60	1,256
				HS Cruise	0.041	0.072	3.36	26.0	1,487
L-2	Cummins	2013	171,974	UDDS	0.022	0.014	9.65	4.90	2,098
				Creep	0.309	0.060	22.32	12.41	5,762
				Near Dock	0.137	0.033	10.70	3.54	2,511
				Local	0.082	0.077	9.42	4.03	2,383
				Cruise	0.013	0.024	1.95	5.43	1,367
				HS Cruise	0.009	0.032	1.57	29.81	1,609

* No data reported

6.6.EMISSION TEST DATE FROM EMA/UCR AND CARB TESTING PROJECT

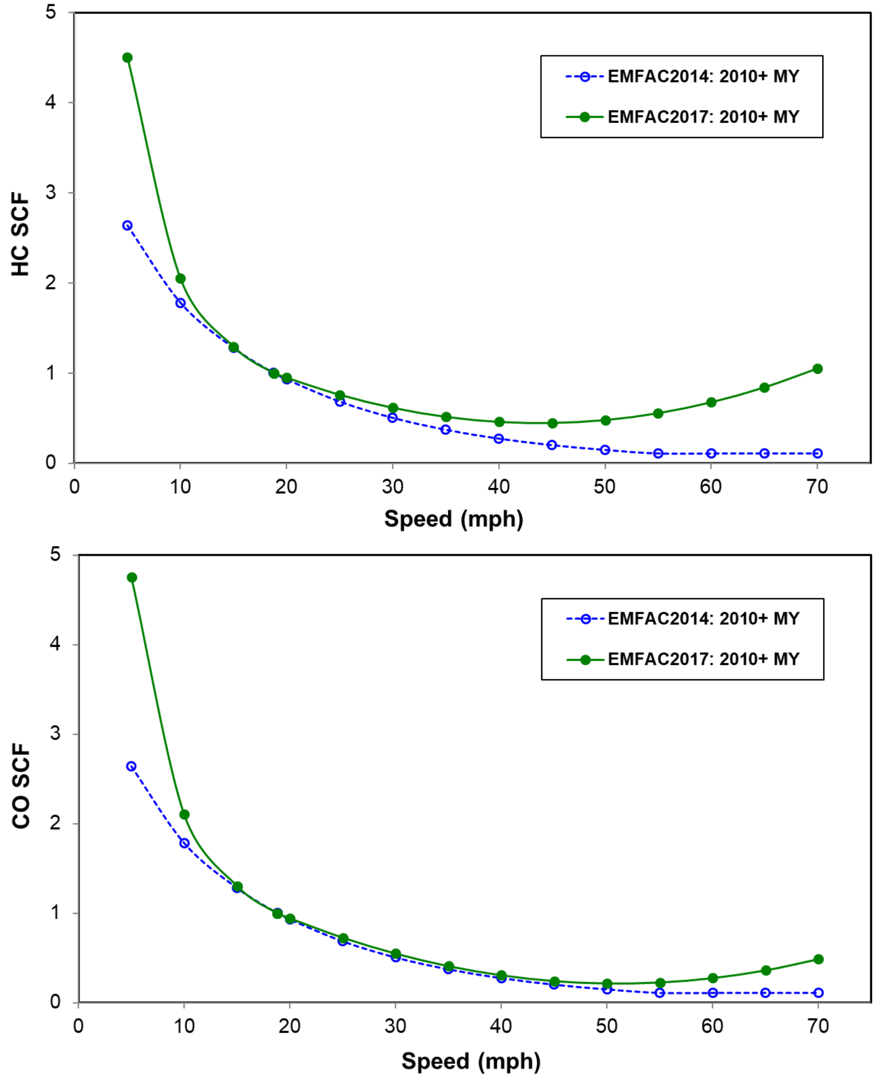
Table 6.6-1. Emission Test Data from EMA/UCR Testing Project

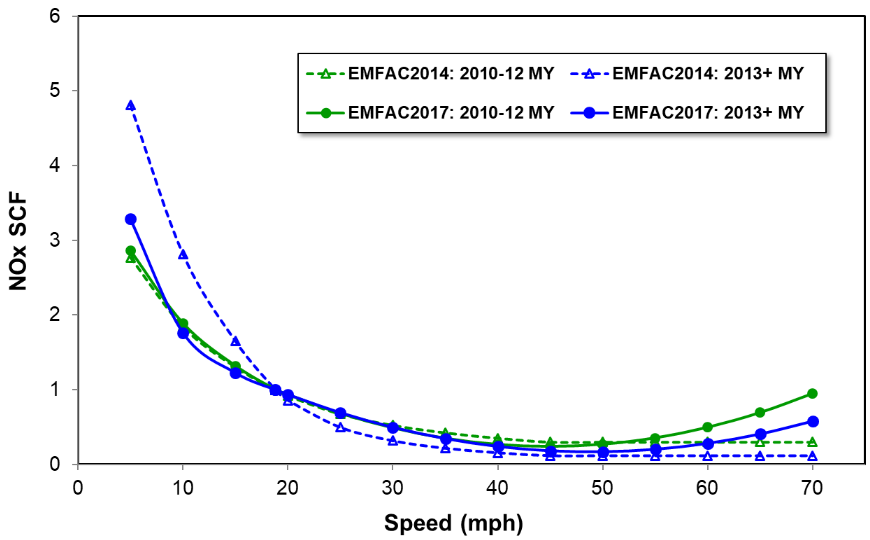
Veh ID	Eng Make	Eng MY	Odometer (mi)	Test Lab	Test Cycle	HC (g/mi)	CO (g/mi)	NO_X (g/mi)	PM (mg/mi)	CO_2 (g/mi)
A1	Cummins	2014	28,611	EMA/UCR	UDDS	0.017	0.162	0.99	6.05	1,865
					Creep	0.391	0.467	5.28	4.31	4,148
					Transient	0.010	0.088	1.82	4.94	2,260
					40-mph Cruise	0.006	0.024	0.07	12.3	1,160
					50-mph Cruise	0.003	0.120	0.07	9.98	1,450
A2	Cummins	2015	2,924	CARB MTA	UDDS	n.r.*	0.080	0.25	5.42	2,273
					Creep	n.r.	0.144	8.05	3.26	5,706
					Transient	n.r.	0.105	0.61	4.39	2,671
					40-mph Cruise	n.r.	0.091	0.21	3.08	1,734
					50-mph Cruise	n.r.	0.092	0.43	3.11	2,082
				EMA/UCR	UDDS	0.000	0.002	1.36	2.18	2,063
					Creep	0.335	0.004	8.80	16.1	4,781
					Transient	-0.002	0.003	3.25	2.89	2,580
					40-mph Cruise	-0.007	0.002	0.12	1.78	1,327
					50-mph Cruise	-0.005	0.002	0.08	6.67	1,707
B	Detroit Diesel	2014	15,914	CARB MTA	UDDS	n.r.	0.148	0.24	16.7	2,046
					Creep	n.r.	0.786	2.77	3.72	3,587
					Transient	n.r.	0.198	0.29	13.1	2,274
					40-mph Cruise	n.r.	0.094	0.31	16.5	1,479
					50-mph Cruise	n.r.	0.085	0.33	44.6	1,786
				EMA/UCR	UDDS	0.026	0.174	0.50	2.51	2,006
					Creep	0.239	0.864	9.50	6.29	3,707
					Transient	0.019	0.105	0.80	1.59	2,436
					40-mph Cruise	0.007	0.101	0.17	2.35	1,264
					50-mph Cruise	0.003	0.090	0.25	2.04	1,596
C	Navistar	2014	7,686	EMA/UCR	UDDS	0.034	0.079	0.81	4.30	2,128
					Creep	0.375	2.447	2.13	4.80	5,095
					Transient	0.024	0.143	1.31	12.2	2,607
					40-mph Cruise	0.003	0.058	0.47	10.2	1,232
					50-mph Cruise	-0.003	0.069	0.22	33.1	1,646

* No data reported

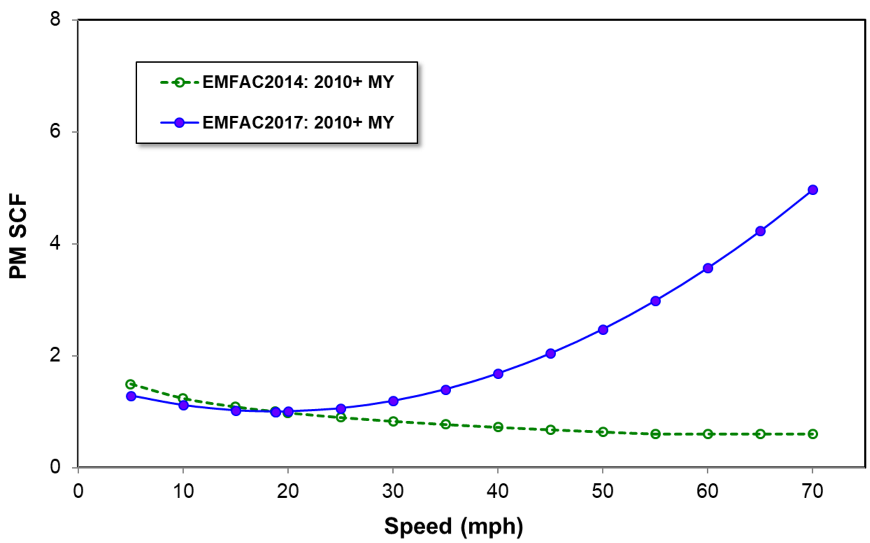
6.7. SPEED CORRECTION FACTORS FOR HEAVY-DUTY DIESEL TRUCKS

Figure 6.7-1. EMFAC2017 Speed Correction Factors for Heavy-Duty Diesel Trucks

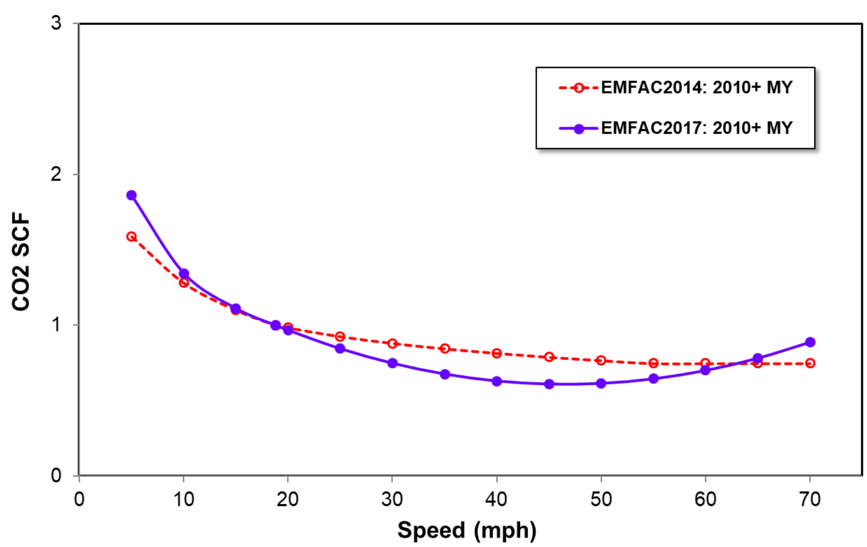




EMFAC2014: 2010-12 MY
EMFAC2014: 2013+ MY
EMFAC2017: 2010-12 MY
EMFAC2017: 2013+ MY
NOx SCF
Speed (mph)



EMFAC2014: 2010+ MY
EMFAC2017: 2010+ MY
PM SCF
Speed (mph)



EMFAC2014: 2010+ MY
EMFAC2017: 2010+ MY
CO2 SCF
Speed (mph)

6.8. IDLE EMISSION RATES OF FOUR HD TRUCKS TESTED USING PEMS

Table 6.8-1. Idle Emission Test Data of Four HD Trucks Tested Using PEMS

Test Vehicle	Engine MY	Cold/Hot Start	HC (g/hr)	CO (g/hr)	NO_X (g/hr)			CO_2 (g/hr)		
			All	All	No Load	w/AC	w/Heater	No Load	w/AC	w/Heater
Detroit Diesel	2011	C	0.64	22.8	21.3	--	--	4,648	--	--
		H	1.79	38.2	23.2	23.0	22.9	7,194	9,052	7,262
Detroit Diesel	2014	C	2.36	65.7	26.4	--	--	8,609	--	--
		H	n.r.*	n.r.	21.9	n.r.	22.7	7,824	10,504	7,974
Paccar	2013	C	2.89	30.4	19.3	--	--	4,775	--	--
		H	1.54	19.5	18.4	17.5	18.4	4,779	6,598	6,291
Volvo	2014	C	0.42	19.5	28.3	--	--	5,185	--	--
		H	0.75	23.6	29.2	27.1	30.1	5,079	5,786	5,065

* No data reported

6.9. IDLE EMISSION RATES FROM TEXAS TRANSPORTATION INSTITUTE PEMS TESTS

Table 6.9-1. Idle Emission Test Data from Texas Transportation Institute PEMS Tests

Truck ID	MY	Hot Emission Rate (g/hr)					Cold Emission Rate (g/hr)				
		THC	CO	NO_X	PM	CO_2	THC	CO	NO_X	PM	CO_2
#6	2010	n.r.*	35.0	21.3	0.050	6,656	2.02	56.5	47.2	0.008	8,282
#7	2011	5.44	12.9	64.2	0.046	6,717	4.07	18.1	25.4	0.103	6,094
#8	2011	5.22	13.2	57.1	0.029	6,029	2.57	17.4	73.1	0.060	11,610
#9	2011	5.4	17.8	25.6	0.039	7,226	3.61	14.8	16.6	0.018	5,647
#10	2011	n.r.	50.1	78.5	0.009	8,459	n.r.	52	99.8	0.028	7,532
#13	2013	1.33	21.7	19.1	0.001	6,589	1.16	26.2	58.2	0.010	8,224
#14	2013	2.84	60.4	32.8	0.001	4,972	0.36	43.5	106	0.002	16,925
#15	2013	1.33	27.7	23.9	0.009	6,859	1.81	54.5	24.2	0.006	5,921

* No data reported

6.10. START NO_X EMISSION RATES FOR DIFFERENT SOAK TIME (G/START)

Table 6.10-1. Start NOx Emission Test Data for Different Soak Times

Test Veh	Eng MY	5 min	10 min	15 min	30 min	60 min	120 min	240 min	720 min
DDC	2011	0.44	0.14	0.00	1.42	1.52	4.14	4.53	13.55
DDC	2014	0.00	n.t.*	1.07	0.39	2.73	3.83	8.97	18.2
Volvo	2014	0.00	2.93	n.t.	2.36	6.38	8.24	14.3	20.8
Paccar	2013	0.84	1.21	n.t.	n.t.	8.45	n.t.	n.t.	n.t.

* No testing data was conducted

6.11. DIESEL TRANSIT BUS EMISSION TEST DATA (G/MI)

Table 6.11-1. Diesel Transit Bus Emission Test Data

Data Source	Model Year	Odometer (mi)	Test Cycle	HC (g/mi)	CO (g/mi)	NO_X (g/mi)	PM (g/mi)	CO_2 (g/mi)
IBIS	1986	766,574	OCBC	2.12	3.92	40.5	0.55	2,734
IBIS	1987	747,557	OCBC	0.51	12.35	36.1	1.28	2,600
IBIS	1990	532,206	OCBC	0.79	0.61	19.4	0.60	2,841
IBIS	1992	509,065	OCBC	0.03	0.14	22.7	0.01	3,464
IBIS	1992	586,458	OCBC	0.18	0.03	14.6	0.01	2,793
IBIS	1996	131,863	OCBC	0.04	0.39	48.4	0.01	3,012
IBIS	1996	132,366	OCBC	0.08	0.37	42.2	0.01	2,635
IBIS	1997	233,671	OCBC	0.13	4.22	23.7	0.65	2,105
IBIS	1997	233,802	OCBC	0.38	2.85	22.8	0.45	1,698
IBIS	2000	227,704	OCBC	0.10	3.20	20.0	0.23	2,405
IBIS	2002	107,686	OCBC	n.r.*	2.44	19.1	0.26	2,200
IBIS	2002	147,288	OCBC	0.05	0.43	18.2	0.21	2,378
IBIS	2002	178,317	OCBC	0.31	2.23	28.1	0.22	3,337
IBIS	2002	181,533	OCBC	n.r.	0.06	30.7	0.01	3,558
IBIS	2004	367,284	OCBC	n.r.	1.01	13.2	0.28	2,392
IBIS	2005	32,497	OCBC	0.14	1.95	11.3	0.24	2,137
IBIS	2005	211,495	OCBC	n.r.	2.24	10.8	0.38	2,039
IBIS	2005	247,912	OCBC	n.r.	1.43	13.4	0.39	2,441
IBIS	2005	803,407	OCBC	n.r.	1.75	14.4	0.63	2,779
IBIS	2006	2,076	OCBC	0.93	3.40	8.98	0.14	2,423

Data Source	Model Year	Odometer (mi)	Test Cycle	HC (g/mi)	CO (g/mi)	NO_X (g/mi)	PM (g/mi)	CO_2 (g/mi)
IBIS	2006	5,635	OCBC	0.36	1.18	8.03	0.12	2,346
IBIS	2006	7,171	OCBC	0.62	1.82	8.76	0.14	2,362
IBIS	2006	212,161	OCBC	0.51	2.67	9.25	0.53	2,563
IBIS	2007	133,293	OCBC	n.r.	0.03	7.07	0.010	2,703
IBIS	2007	137,086	OCBC	n.r.	0.11	6.99	0.008	2,119
IBIS	2007	168,819	OCBC	n.r.	0.05	8.17	0.009	2,517
IBIS	2007	173,918	OCBC	n.r.	0.24	7.13	0.031	2,586
IBIS	2007	403,699	OCBC	n.r.	0.14	8.31	0.011	2,345
IBIS	2008	119,193	OCBC	n.r.	0.05	8.57	0.007	2,359
VTA	2012	54,000	OCBC	n.r.	0.06	0.95	0.002	2,089
VTA	2012	110,000	OCBC	n.r.	0.32	1.79	0.001	2,149
Altoona	2010	n.r.	OCBC	n.r.	n.r.	0.99	0.006	2,084
Altoona	2011	n.r.	OCBC	n.r.	n.r.	0.92	0.016	1,950
Altoona	2011	n.r.	OCBC	n.r.	n.r.	4.20	0.002	2,189
Altoona	2013	n.r.	OCBC	n.r.	n.r.	0.47	0.003	1,807
Altoona	2013	n.r.	OCBC	n.r.	n.r.	1.99	0.003	1,672
Altoona	2014	n.r.	OCBC	n.r.	n.r.	1.34	0.002	2,230
Altoona	2014	n.r.	OCBC	n.r.	n.r.	1.44	0.004	2,298
Altoona	2015	n.r.	OCBC	n.r.	n.r.	2.91	0.021	1,817

*No testing data was conducted

** No data reported

6.12. CNG TRANSIT BUS EMISSION TEST DATA

Table 6.12-1. CNG Transit Bus Emission Test Data

Data Source	Model Year	Odometer (mi)	Test Cycle	HC (g/mi)	CO (g/mi)	NO_X (g/mi)	PM (g/mi)	CO_2 (g/mi)
WVU IBIS	2005	3,148	OCBC	17.4	0.07	12.8	0.013	1,768
WVU IBIS	2005	4,225	OCBC	12.1	-	11.0	0.009	1,823
WVU IBIS	2005	4,719	OCBC	29.9	0.46	18.7	0.009	2,112
WVU IBIS	2005	7,717	OCBC	17.3	0.06	10.6	0.011	1,863
WVU IBIS	2005	18,593	OCBC	22.7	0.43	19.6	0.027	2,164
WVU IBIS	2005	26,858	OCBC	30.4	1.08	21.3	0.013	2,156
WVU IBIS	2005	159,112	OCBC	24.3	2.88	22.3	0.025	2,255
WVU IBIS	2006	93,294	OCBC	13.4	1.68	20.4	0.014	2,240
WVU IBIS	2008	28,422	OCBC	15.6	142.2	0.67	0.016	3,062
WVU IBIS	2008	34,755	OCBC	10.0	65.1	0.99	0.010	3,263
ARB MLD	2008	226,667	OCBC	6.20	58.9	0.51	n.r.	2,781
ARB MLD	2008	228,385	OCBC	8.90	69.6	1.39	n.r.	2,493
VTA-ARB	2011	71,500	OCBC	3.90	21.6	0.78	0.001	2,305
VTA-ARB	2011	112,300	OCBC	9.72	42.4	1.07	0.001	2,214
VTA-ARB	2012	209,000	OCBC	6.67	48.7	1.02	0.001	2,270
Altoona	2010	n.r.*	OCBC	n.r.	n.r.	0.14	n.r.	1,853
Altoona	2010	n.r.	OCBC	n.r.	n.r.	0.26	n.r.	1,895
Altoona	2011	n.r.	OCBC	n.r.	n.r.	0.77	n.r.	1,641
Altoona	2011	n.r.	OCBC	n.r.	n.r.	0.30	n.r.	1,932
Altoona	2012	n.r.	OCBC	n.r.	n.r.	0.52	n.r.	2,036
Altoona	2012	n.r.	OCBC	n.r.	n.r.	0.40	n.r.	1,725
Altoona	2013	n.r.	OCBC	n.r.	n.r.	0.32	n.r.	1,912
Altoona	2013	n.r.	OCBC	n.r.	n.r.	0.45	n.r.	1,820
Altoona	2014	n.r.	OCBC	n.r.	n.r.	0.46	n.r.	2,095
Altoona	2015	n.r.	OCBC	n.r.	n.r.	0.23	n.r.	2,559

* No data reported

6.13. EMISSION DATA FROM CARB CROSS CALIFORNIA PEMS TESTING OF CNG TRANSIT BUS

Table 6.13-1. Emission Data from CARB Cross California PEMS Testing of a CNG Transit Bus

Cycle / Route	Average Speed (mph)	HC (g/mi)	CO (g/mi)	NO_X (g/mi)	PM (g/mi)	CO_2 (g/mi)
Regional	29.2	1.67	6.77	0.24	9.4	1,335
Neardock	9.2	5.03	9.06	0.38	12.4	2,369
Local	15.6	1.37	14.4	0.46	8.3	2,214
Regional	29.2	1.47	11.4	0.24	3.5	1,731
I-5 / I-15 Hill Climb	39.2	3.91	9.82	0.48	--	2,018
Interstate	41.3	1.63	9.23	0.15	3.2	1,555
Interstate	37.1	2.36	7.55	0.24	2.9	1,300
Regional	35.4	1.47	8.23	0.17	2.2	1,376
Regional	41.8	1.89	9.31	0.26	1.9	1,549
I-5 / I-15 Hill Climb	37.1	3.53	8.34	0.38	2.0	2,185
Interstate	52.4	1.88	6.33	0.11	3.1	1,294

6.14. LD AND HD ACTIVITY PROFILE

Table 6.14-1 EMFAC LDV Hourly Start Distribution (%)

Hour	EMFAC2014	EMFAC2017
1	0.84	0.3
2	0.41	0.22
3	0.15	0.07
4	0.17	0.09
5	0.28	0.16
6	0.45	0.97
7	1.91	2.75
8	5.7	5.07
9	5.64	5.42
10	4.72	5.06
11	5.06	5.4
12	7.19	6.22
13	8.31	7.38
14	6.92	6.93
15	7.38	7.17
16	7.78	7.5
17	7.43	8.31
18	7.89	9.5
19	6.41	7.51
20	5.11	5.92
21	3.42	3.52
22	2.97	2.63
23	2.09	1.3
24	1.76	0.60

Table 6.14-2. EMFAC HD Soak Time Bin Definition

Soak Period ID	Soak Period Bin	Definition
1	5	<= 5 min
2	10	>5 min and <=10 min
3	20	> 10 min and <=20 min
4	30	> 20 min and <= 30 min
5	40	> 30 min and <= 40 min
6	50	> 40 min and <= 50 min
7	60	> 50 min and <= 60 min
8	120	> 60 min and <= 120 min
9	180	> 120 min and <=180 min
10	240	> 180 min and <=240 min
11	300	> 240 min and <=300 min
12	360	>300 min and <=360 min
13	420	> 360 min and <=420 min
14	480	> 420 min and <=480 min
15	540	> 480 min and <=540 min
16	600	> 540 min and <=600 min
17	660	> 600 min and <=660 min
18	720	> 660 min and <=720 min
19	9999	> 720 min

Table 6.14-3a HD Soak Time Distribution for Vocation-Region Group 1a – Line Haul- Out of State

Hour of Day	Soak Time (minutes)																			% of Starts by Hour
	5	10	20	30	40	50	60	120	180	240	300	360	420	480	540	600	660	720	721+	
1	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.09	0.00	0.03	0.03	0.21
2	0.43	0.27	0.06	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.09	0.12	0.43	0.58	0.52	0.95	3.48
3	0.49	0.34	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.12	0.09	0.06	0.15	1.43
4	2.04	0.55	0.12	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.46	0.27	0.34	0.64	4.48
5	0.24	0.18	0.12	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.03	0.06	0.76
6	0.27	0.15	0.18	0.06	0.03	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.82
7	2.35	1.04	0.46	0.61	0.18	0.06	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	4.88
8	5.82	1.77	1.13	0.64	0.76	0.52	0.15	0.09	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.91
9	11.71	3.14	1.07	0.55	0.18	0.27	0.03	0.06	0.03	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.06	17.16
10	10.18	3.05	1.80	0.52	0.30	0.06	0.06	0.09	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.15	16.28
11	4.30	1.49	1.07	0.55	0.46	0.24	0.37	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	8.96
12	4.27	1.40	0.91	0.27	0.15	0.09	0.06	0.40	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	7.71
13	1.10	0.40	0.37	0.03	0.03	0.00	0.12	0.15	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	2.23
14	1.77	1.40	1.01	0.18	0.06	0.03	0.06	0.70	0.09	0.09	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	5.49
15	1.92	1.07	1.07	0.27	0.18	0.06	0.00	0.06	0.12	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	4.97
16	1.43	1.19	0.79	0.18	0.06	0.24	0.15	0.27	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	4.45
17	0.95	0.67	0.49	0.18	0.15	0.03	0.03	0.21	0.12	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	2.90
18	0.55	0.70	0.21	0.03	0.00	0.12	0.06	0.18	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	1.98
19	0.09	0.21	0.09	0.03	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49
20	0.09	0.03	0.03	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18
21	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.03
24	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
% of Starts by Soak Bin	50.00	19.12	11.13	4.15	2.56	1.80	1.19	2.77	0.61	0.21	0.21	0.03	0.03	0.24	0.15	1.13	1.04	1.01	2.62	100

Table 6.14-3b HD Soak Time Distribution for Vocation-Region Group 1b – Line Haul- instate

Hour of Day	Soak Time (minutes)																			% of Starts by Hour
	5	10	20	30	40	50	60	120	180	240	300	360	420	480	540	600	660	720	721+	
1	2.20	0.73	0.42	0.00	0.10	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.67
2	1.57	1.26	0.52	0.21	0.21	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.88
3	0.42	0.31	0.31	0.31	0.21	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.68
4	0.94	0.31	1.05	0.31	0.10	0.00	0.10	0.21	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	3.15
5	0.42	0.52	0.21	0.21	0.00	0.10	0.00	0.10	0.21	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.31	2.31
6	2.73	1.05	0.42	0.10	0.10	0.10	0.10	0.52	0.42	0.00	0.10	0.10	0.00	0.00	0.00	0.10	0.21	0.21	0.31	6.61
7	1.57	0.31	0.84	0.31	0.10	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.46
8	1.68	0.63	0.63	0.10	0.00	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10	3.57
9	2.31	0.42	1.05	0.31	0.00	0.00	0.10	0.21	0.00	0.10	0.00	0.00	0.00	0.00	0.10	0.21	0.00	0.00	0.00	4.83
10	2.31	0.84	0.52	0.21	0.31	0.10	0.42	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.93
11	2.62	0.94	0.63	0.21	0.21	0.21	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10	0.10	0.10	5.67
12	3.15	0.94	1.05	0.00	0.21	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	5.88
13	2.62	0.63	0.84	0.31	0.00	0.21	0.10	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	5.14
14	1.99	2.10	0.63	0.10	0.10	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	5.56
15	1.57	0.73	1.15	0.21	0.31	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.20
16	1.15	1.05	0.73	0.42	0.21	0.00	0.00	0.10	0.21	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.09
17	2.31	1.15	0.52	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	4.51
18	1.99	1.36	0.63	0.52	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.72
19	2.10	0.52	0.52	0.00	0.10	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.36
20	2.41	0.94	0.52	0.21	0.10	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.41
21	1.47	0.63	0.31	0.21	0.00	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	2.94
22	2.31	0.84	0.42	0.21	0.10	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.99
23	2.52	0.94	0.63	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.30
24	1.57	0.84	0.31	0.31	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.15
% of Starts by Soak Bin	45.96	20.04	14.90	4.83	2.73	1.47	1.36	3.57	1.36	0.31	0.10	0.10	0.00	0.10	0.42	0.42	0.52	0.42	1.36	100

Table 6.14-3c HD Soak Time Distribution for Vocation-Region Group 2b – Drayage trucks

Hour of Day	Soak Time (minutes)																			% of Starts by Hour
	5	10	20	30	40	50	60	120	180	240	300	360	420	480	540	600	660	720	721+	
1	4.33	0.70	0.52	0.22	0.16	0.08	0.00	0.12	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.16
2	4.17	0.62	0.68	0.20	0.22	0.02	0.04	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.02
3	2.45	0.32	0.38	0.14	0.14	0.08	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	3.55
4	0.56	0.08	0.28	0.06	0.12	0.12	0.08	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.53
5	0.08	0.10	0.04	0.00	0.06	0.02	0.00	0.08	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.04
7	1.00	0.28	0.14	0.04	0.00	0.00	0.00	0.02	0.18	0.24	0.16	0.08	0.04	0.00	0.00	0.00	0.00	0.02	0.66	2.87
8	2.29	0.52	0.20	0.02	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	3.11
9	2.83	0.58	0.42	0.08	0.02	0.02	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	4.11
10	2.29	0.40	0.52	0.08	0.12	0.06	0.02	0.04	0.00	0.00	0.02	0.02	0.08	0.02	0.02	0.00	0.00	0.02	0.06	3.77
11	2.11	0.68	0.32	0.10	0.06	0.08	0.00	0.06	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.06	3.51
12	2.59	0.52	0.34	0.04	0.00	0.04	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	3.59
13	1.71	0.50	0.36	0.20	0.04	0.00	0.04	0.06	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	3.05
14	1.91	0.34	0.48	0.16	0.20	0.04	0.10	0.12	0.00	0.02	0.04	0.00	0.00	0.00	0.02	0.04	0.00	0.02	0.12	3.61
15	1.97	0.28	0.32	0.10	0.24	0.08	0.04	0.04	0.00	0.00	0.04	0.02	0.00	0.02	0.00	0.00	0.00	0.02	0.02	3.19
16	1.49	0.34	0.20	0.04	0.08	0.10	0.12	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	2.45
17	1.26	0.38	0.22	0.18	0.10	0.06	0.00	0.04	0.00	0.04	0.04	0.00	0.06	0.02	0.00	0.00	0.02	0.02	0.84	3.29
18	2.99	0.60	0.36	0.16	0.06	0.06	0.04	0.16	0.14	0.06	0.06	0.02	0.00	0.02	0.00	0.00	0.00	0.06	1.06	5.86
19	5.32	1.12	0.54	0.20	0.06	0.00	0.00	0.14	0.04	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.06	7.53
20	4.01	1.49	0.72	0.26	0.04	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	6.66
21	4.54	1.49	0.88	0.36	0.14	0.04	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	7.51
22	4.74	1.08	0.62	0.20	0.06	0.08	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	6.84
23	3.13	1.02	0.50	0.24	0.14	0.06	0.04	0.10	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.26
24	3.23	0.78	0.64	0.28	0.30	0.22	0.04	0.50	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.08
% of Starts by Soak Bin	60.99	14.25	9.71	3.37	2.37	1.36	0.62	1.87	0.58	0.44	0.42	0.18	0.22	0.08	0.04	0.06	0.08	0.16	3.19	100

6.15. LIGHT DUTY VMT SPATIAL ALLOCATION

The Institute of Transportation Studies at the University of California, Irvine developed CalVAD tool for CARB. CalVAD tool merges data from different data sources related to roadway vehicle activity. The primary sources of data are the Weigh in Motion (WIM) and the Vehicle Detection Systems (VDS). These data sources produce significant volume of data from detectors scattered throughout the state. The tool developed pulls in data from both of these data sources and merges these sets based on time, geographic proximity, and statistical imputation techniques. The data from Highway Performance Monitoring System (HPMS) is also included.

EMFAC2014 is the latest EPA-approved mobile source emission inventory model for estimating emissions and VMT for the State of California. EMFAC2014 default VMT are based upon a relationship between California Board of equalization (BOE) fuel sales, vehicle population, and mileage accrual data. Fuel-based regional VMT are also spatially corrected for inter-regional traffic using data from the HPMS, commercial truck travel surveys, and other vehicle class specific distributions.

CalVAD tool estimates the total VMT for each county in California. The VMT is also estimated for two vehicle classification namely, Non-Heavy Heavy Duty vehicles, (NHH) with gross vehicle weight between 22,001 and 33,000 lbs. and Heavy Heavy Duty Vehicles (HH) with gross vehicle weight above 33,000 for most of the counties. In order to compare percent distribution of LDV VMT for each GAI the following assumptions were made:

(1) For CalVAD tool, the LDV VMT (CalVAD) was calculated by subtracting NHH VMT and HH VMT from Total VMT. The LDV VMT (CalVAD) from CalVAD tools represent the VMT accumulated by all vehicles with gross vehicle weight less than 22,000 lbs. GVWR.

(2) The EMFAC2014 estimates VMT for different vehicles categories. In order to match the LDV VMT estimated for vehicles by CalVAD tool, certain categories of vehicles from EMFAC2014 were included as LDV VMT (EMFAC2014).

(3) CalVAD tool estimates VMT per hour for all most all links in California. The Total VMT for the year would be the sum total of all hourly VMT for the entire year.

(4) EMFAC2014 model estimates daily VMT but assumes fewer than 365 days of operation per year for each vehicle category. The Total VMT for the year would be summation of Daily VMT multiplied by the number of operation days per year over all vehicles included in LDV.

The following are the EMFAC2014 categories of vehicle included in this analysis and their corresponding number of days of operation per year:

a) Light Duty Autos (LDA), 347 days
b) Light Duty Trucks 1 and 2 (LDT1 and LDT2), 347 days
c) Light Heavy Duty Trucks 1 and 2 (LHDT1 and LHDT2), 327 days
d) Motor Cycles (MCY), 347 days

e) Medium Duty Vehicles (MDV), 347 days
f) Motor Homes (MH), 327 days
g) T6 CAIRP small, Diesel, 312 days
h) T6 instate construction small, Diesel, 312 days
i) T6 instate small, Diesel, 312 days
j) T6 OOS small, Diesel, 312 days
k) T6TS, Gasoline, 327 days

Table 6.14-1 outlines the total LDV VMT from CalVAD and EMFAC2014 tools for each GAI and the associated percent distribution.

Table 6.15-1. Comparison of LDV VMT (CalVAD) with LDV VMT (EMFAC2014) for the year 2015 for each GAI.

Region	CalVAD		EMFAC2014	
	LDV VMT per year	Percentage	LDV VMT per year	Percentage
Alpine (GBV)	52,786,089	0.02%	63,506,304	0.02%
Inyo (GBV)	566,539,321	0.21%	530,966,663	0.18%
Mono (GBV)	288,673,622	0.11%	296,275,770	0.10%
Lake (LC)	563,548,744	0.21%	493,411,904	0.17%
El Dorado (LT)	142,769,842	0.05%	161,410,373	0.05%
Placer (LT)	131,020,323	0.05%	130,823,760	0.04%
Amador (MC)	259,803,254	0.10%	434,484,894	0.15%
Calaveras (MC)	321,490,008	0.12%	355,389,588	0.12%
El Dorado (MC)	1,037,720,781	0.39%	1,236,259,455	0.41%
Mariposa (MC)	129,949,840	0.05%	172,537,400	0.06%
Nevada (MC)	863,522,552	0.32%	988,302,894	0.33%
Placer (MC)	741,610,941	0.28%	740,498,337	0.25%
Plumas (MC)	235,222,020	0.09%	254,474,965	0.09%
Sierra (MC)	96,136,125	0.04%	89,945,776	0.03%
Tuolumne (MC)	488,309,388	0.18%	380,692,602	0.13%
Kern (MD)	1,161,032,255	0.43%	1,406,612,421	0.47%
Los Angeles (MD)	1,849,415,499	0.69%	1,897,732,258	0.64%
San Bernardino (MD)	4,278,447,614	1.59%	7,802,346,442	2.62%
Riverside (MD/MDAQMD)	277,309,669	0.10%	410,720,075	0.14%
Riverside (MD/SCAQMD)	257,558,467	0.10%	381,466,802	0.13%
Del Norte (NC)	222,368,846	0.08%	220,615,279	0.07%
Humboldt (NC)	1,064,086,131	0.40%	1,059,945,358	0.36%
Mendocino (NC)	1,001,789,552	0.37%	955,360,150	0.32%
Sonoma (NC)	529,860,590	0.20%	547,387,162	0.18%
Trinity (NC)	291,278,785	0.11%	181,240,748	0.06%
Monterey (NCC)	2,881,318,556	1.07%	3,187,832,810	1.07%

Region	CalVAD		EMFAC2014	
	LDV VMT per year	Percentage	LDV VMT per year	Percentage
San Benito (NCC)	402,223,447	0.15%	553,172,471	0.19%
Santa Cruz (NCC)	1,544,968,098	0.58%	1,364,067,644	0.46%
Lassen (NEP)	405,399,859	0.15%	366,507,204	0.12%
Modoc (NEP)	114,662,470	0.04%	130,394,422	0.04%
Siskiyou (NEP)	708,331,296	0.26%	893,735,863	0.30%
Los Angeles (SC)	69,965,644,397	26.05%	72,639,297,775	24.35%
Orange (SC)	24,373,975,617	9.07%	25,500,154,794	8.55%
Riverside (SC)	8,234,060,703	3.07%	12,195,370,006	4.09%
San Bernardino (SC)	6,332,272,599	2.36%	11,547,782,990	3.87%
San Luis Obispo (SCC)	2,300,745,720	0.86%	2,729,545,383	0.91%
Santa Barbara (SCC)	2,746,566,304	1.02%	3,493,858,616	1.17%
Ventura (SCC)	4,790,177,782	1.78%	6,144,147,542	2.06%
San Diego (SD)	26,157,761,773	9.74%	25,504,090,443	8.55%
Alameda (SF)	11,077,248,396	4.12%	12,949,390,889	4.34%
Contra Costa (SF)	7,326,464,415	2.73%	7,735,373,593	2.59%
Marin (SF)	2,107,336,380	0.78%	2,532,623,743	0.85%
Napa (SF)	1,018,387,581	0.38%	978,321,827	0.33%
San Francisco (SF)	2,637,194,282	0.98%	3,076,243,211	1.03%
San Mateo (SF)	5,840,362,355	2.17%	5,902,318,836	1.98%
Santa Clara (SF)	11,975,867,005	4.46%	14,857,402,444	4.98%
Solano (SF)	2,296,401,287	0.85%	3,107,095,666	1.04%
Sonoma (SF)	2,252,898,268	0.84%	2,327,418,972	0.78%
Fresno (SJV)	6,444,091,950	2.40%	4,779,997,703	1.60%
Kern (SJV)	6,795,128,102	2.53%	6,650,058,175	2.23%
Kings (SJV)	1,418,258,146	0.53%	1,246,838,187	0.42%
Madera (SJV)	1,467,282,942	0.55%	1,531,510,872	0.51%
Merced (SJV)	1,611,176,272	0.60%	2,379,434,800	0.80%
San Joaquin (SJV)	3,739,471,283	1.39%	6,635,341,923	2.22%
Stanislaus (SJV)	3,608,939,195	1.34%	3,107,893,013	1.04%
Tulare (SJV)	3,408,898,463	1.27%	2,789,623,278	0.94%
Imperial (SS)	2,499,824,917	0.93%	1,730,046,707	0.58%
Riverside (SS)	2,051,424,893	0.76%	3,038,341,168	1.02%
Butte (SV)	1,459,794,145	0.54%	1,182,825,680	0.40%
Colusa (SV)	504,673,037	0.19%	643,027,932	0.22%
Glenn (SV)	436,218,379	0.16%	488,409,737	0.16%
Placer (SV)	1,965,614,301	0.73%	1,962,665,382	0.66%
Sacramento (SV)	9,943,689,829	3.70%	11,528,927,378	3.86%
Shasta (SV)	1,637,063,236	0.61%	1,743,655,392	0.58%

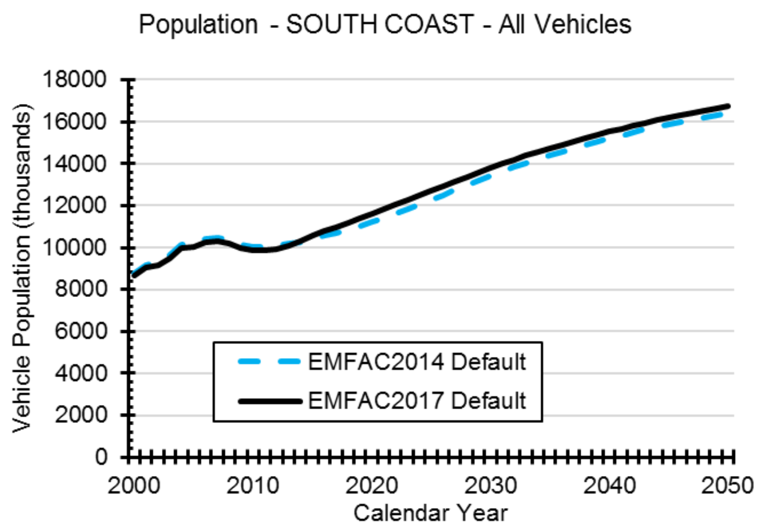
Region	CalVAD		EMFAC2014	
	LDV VMT per year	Percentage	LDV VMT per year	Percentage
Solano (SV)	1,274,907,210	0.47%	1,724,985,389	0.58%
Sutter (SV)	794,969,984	0.30%	733,961,481	0.25%
Tehama (SV)	794,194,546	0.30%	949,392,680	0.32%
Yolo (SV)	1,849,735,054	0.69%	2,012,320,587	0.67%
Yuba (SV)	562,178,111	0.21%	560,891,103	0.19%
Total Statewide LDV VMT per year	268,610,052,840	100.00%	298,328,703,087	100.00%

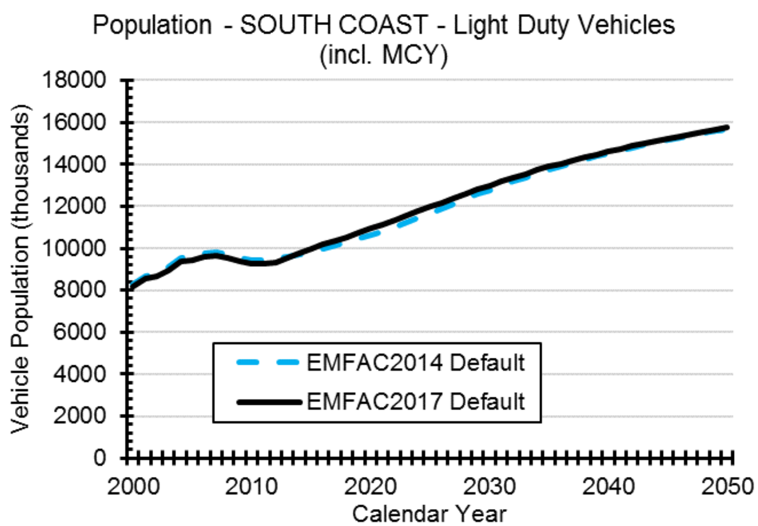
Percent VMT by region from CalVAD data were used to update VMT spatial allocation in EMFAC2017 model.

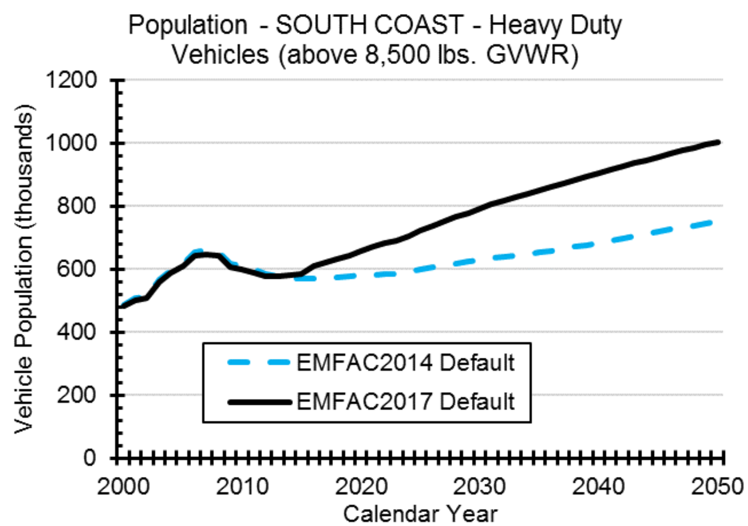
6.16. REGIONAL COMPARISON BETWEEN EMFAC2017 AND EMFAC2014

Figure 6.16-1. Comparison of Vehicle Activity and Emissions in South Coast air basin between EMFAC2014 and EMFAC2017

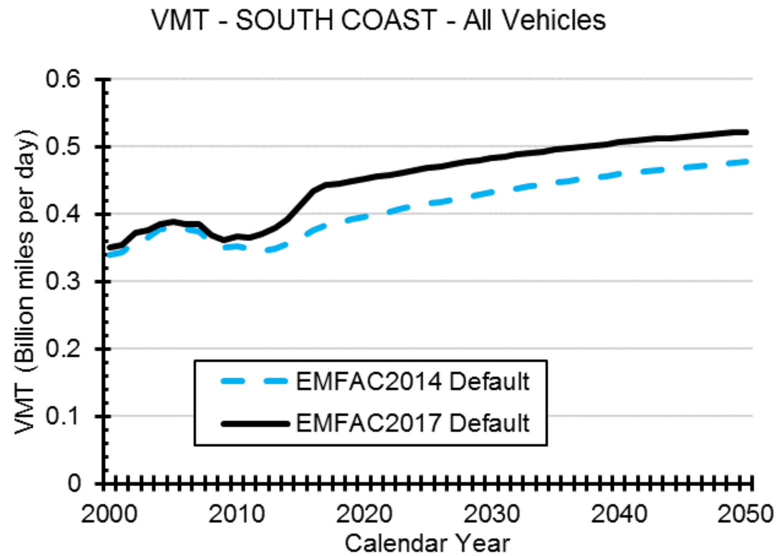
Vehicle Population



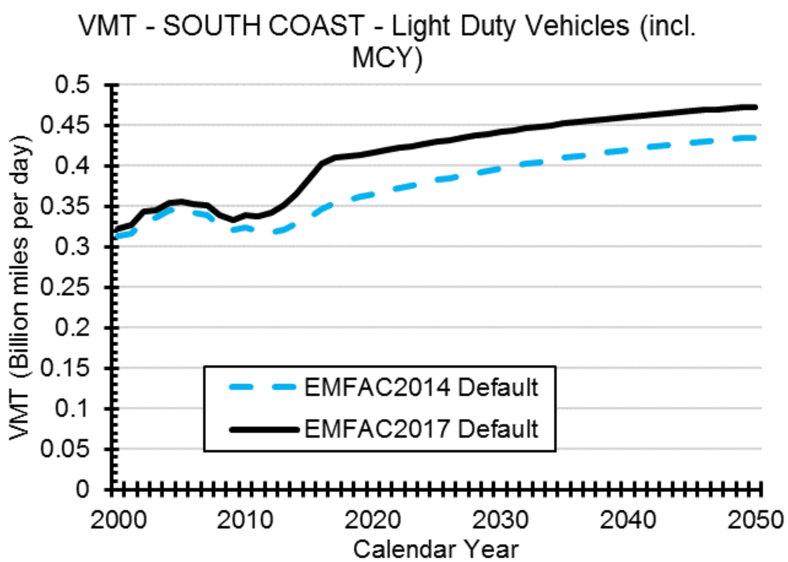




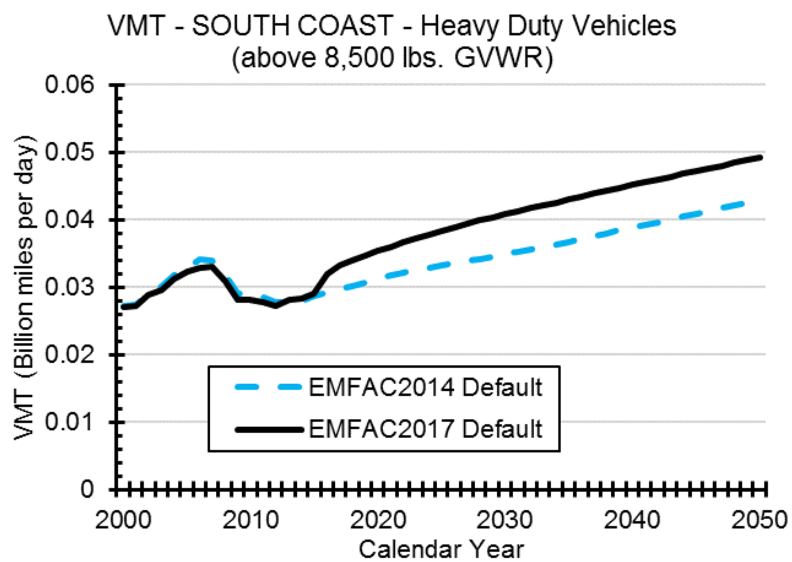
VMT



VMT - SOUTH COAST - All Vehicles
VMT (Billion miles per day)
0
0.1
0.2
0.3
0.4
0.5
0.6
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default

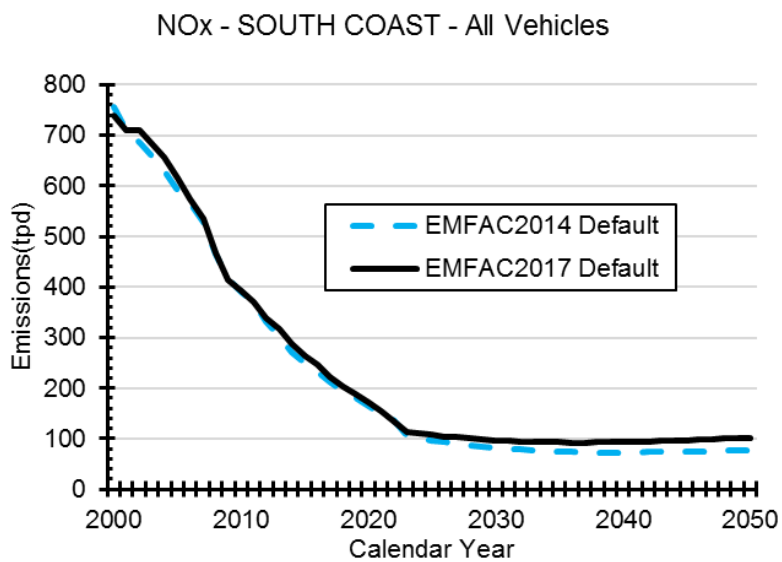


VMT - SOUTH COAST - Light Duty Vehicles (incl. MCY)
VMT (Billion miles per day)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default

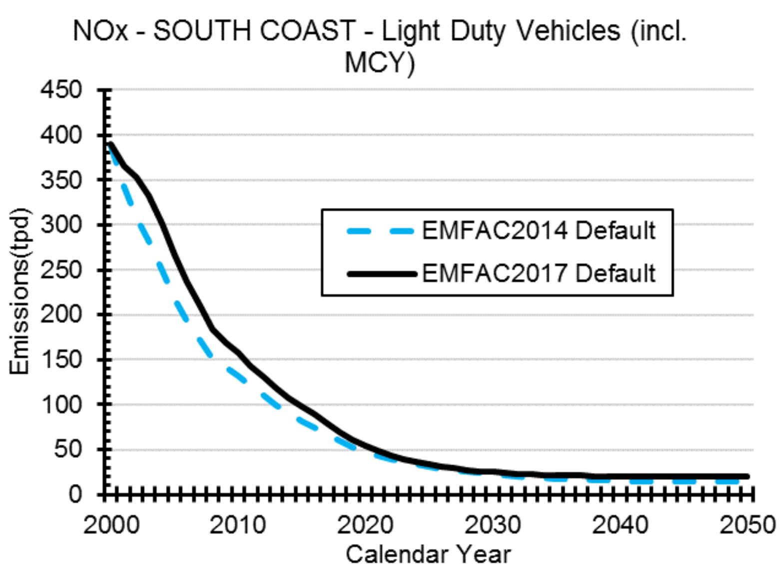


VMT - SOUTH COAST - Heavy Duty Vehicles (above 8,500 lbs. GVWR)
VMT (Billion miles per day)
0
0.01
0.02
0.03
0.04
0.05
0.06
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default

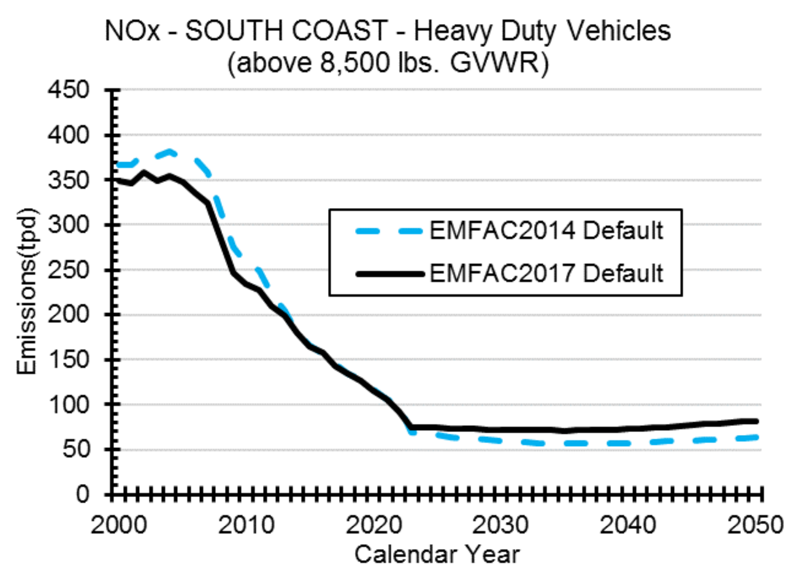
NOX



NOx - SOUTH COAST - All Vehicles
Emissions(tpd)
800
700
600
500
400
300
200
100
0
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default

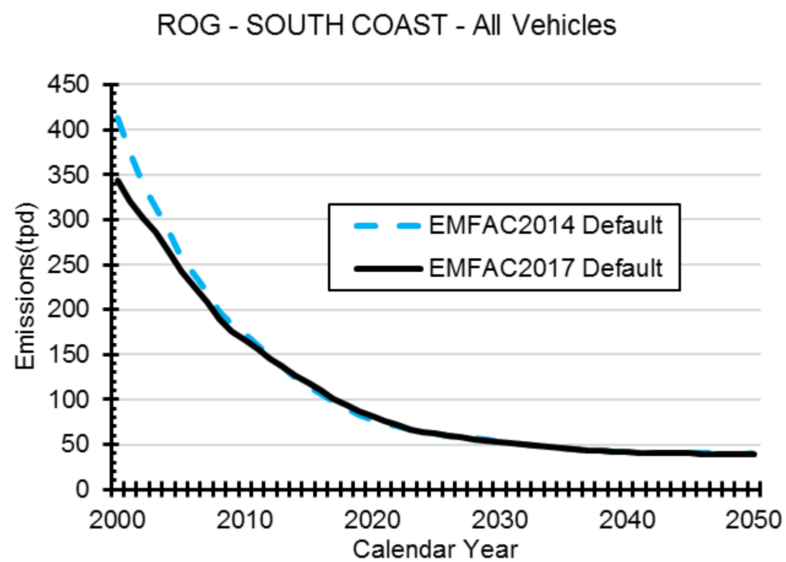


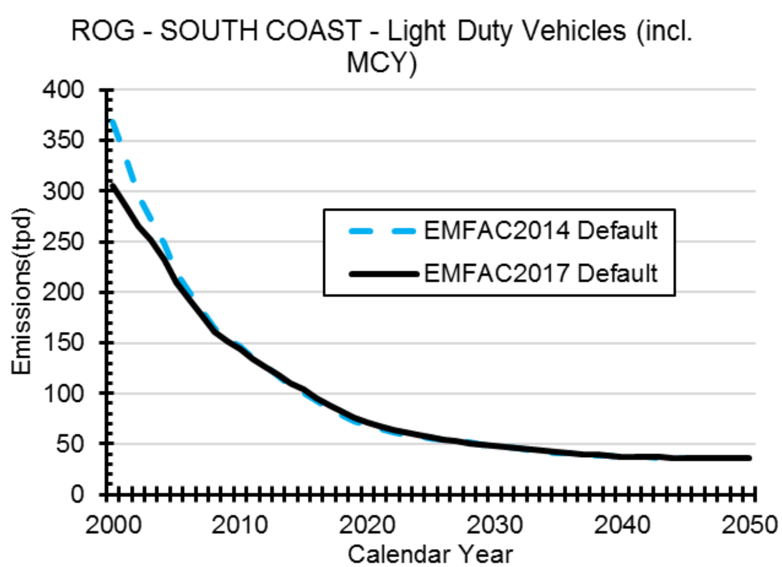
NOx - SOUTH COAST - Light Duty Vehicles (incl. MCY)
Emissions(tpd)
450
400
350
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default

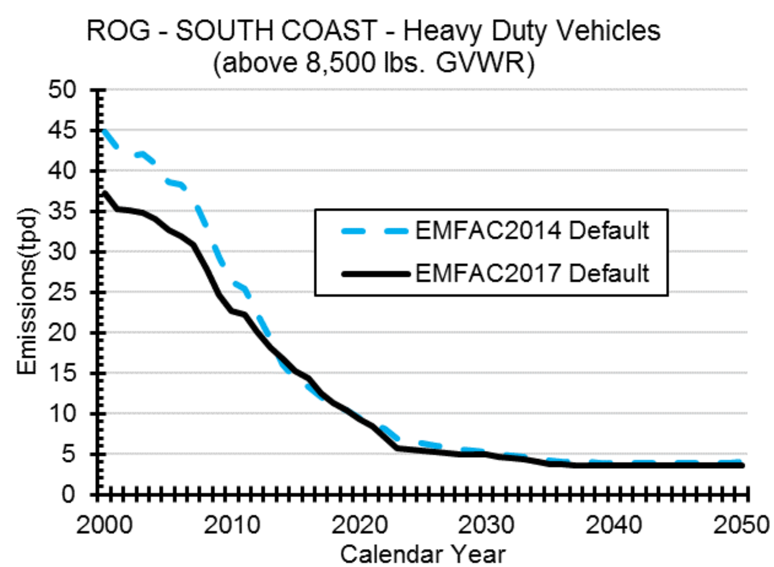


NOx - SOUTH COAST - Heavy Duty Vehicles (above 8,500 lbs. GVWR)
Emissions(tpd)
450
400
350
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default

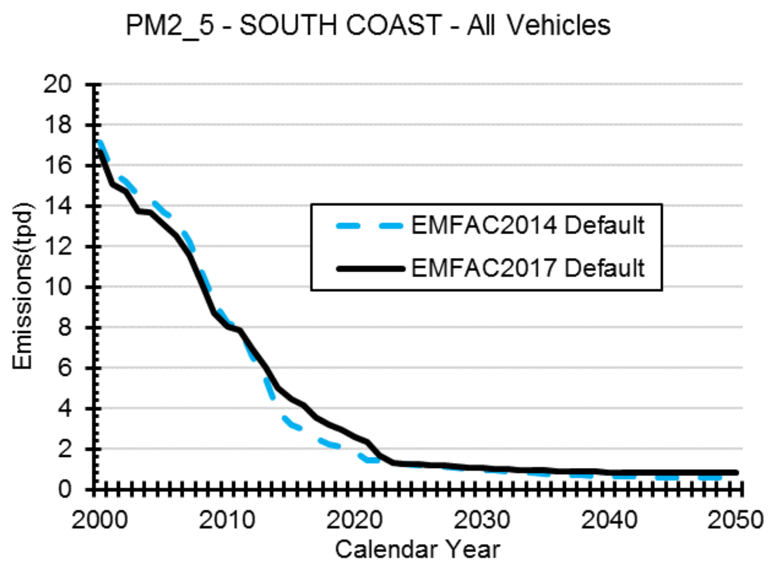
ROG

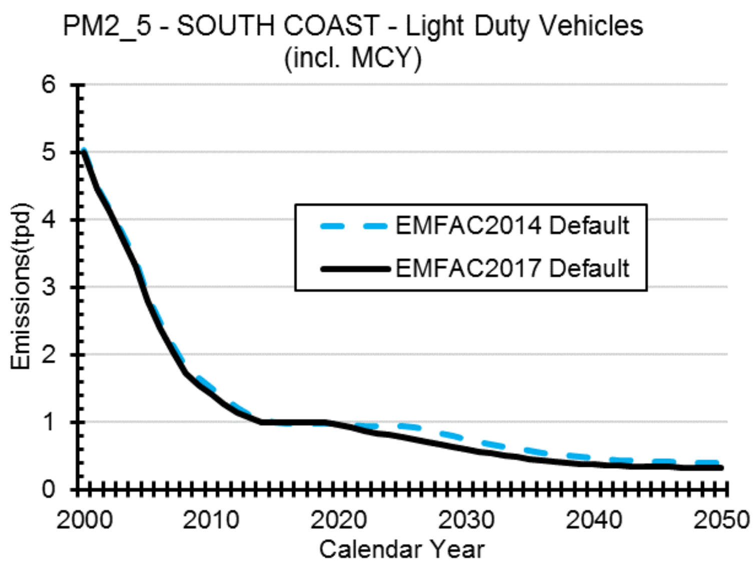

ROG - SOUTH COAST - All Vehicles
Emissions(tpd)
450
400
350
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default

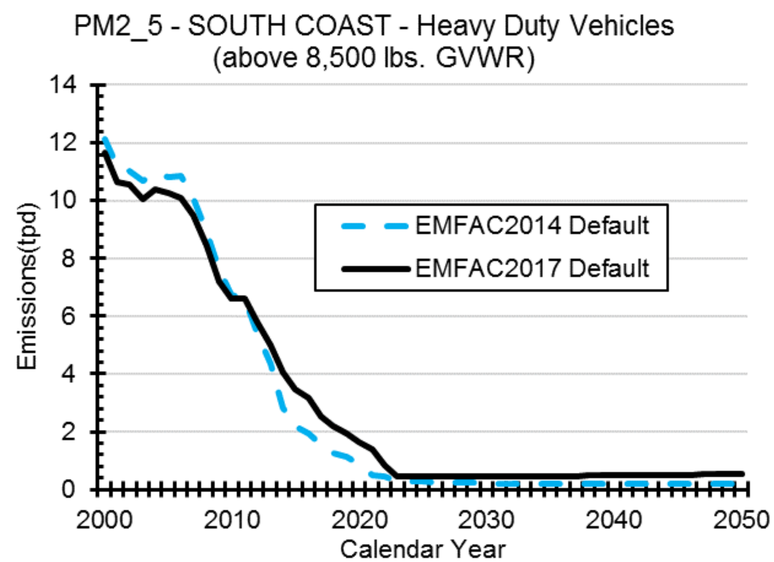

ROG - SOUTH COAST - Light Duty Vehicles (incl. MCY)
Emissions(tpd)
400
350
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default


ROG - SOUTH COAST - Heavy Duty Vehicles (above 8,500 lbs. GVWR)
Emissions(tpd)
50
45
40
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default

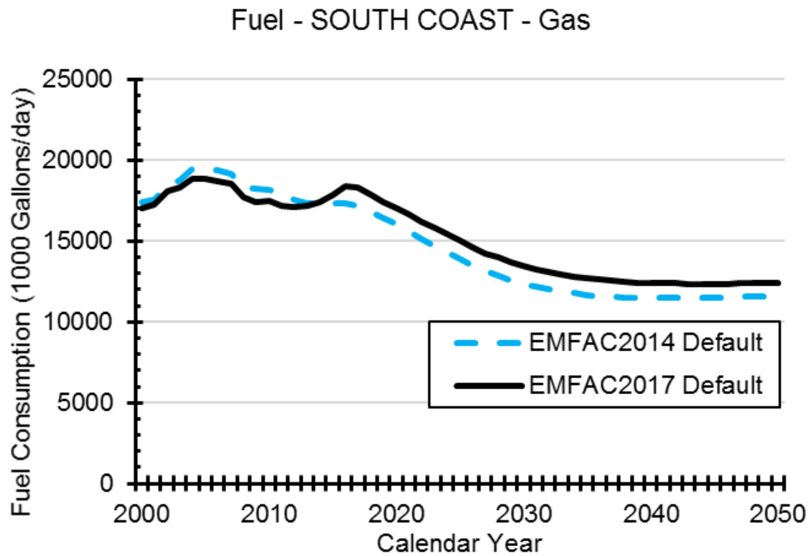
PM2.5 (Tailpipe)







Fuel Consumptions



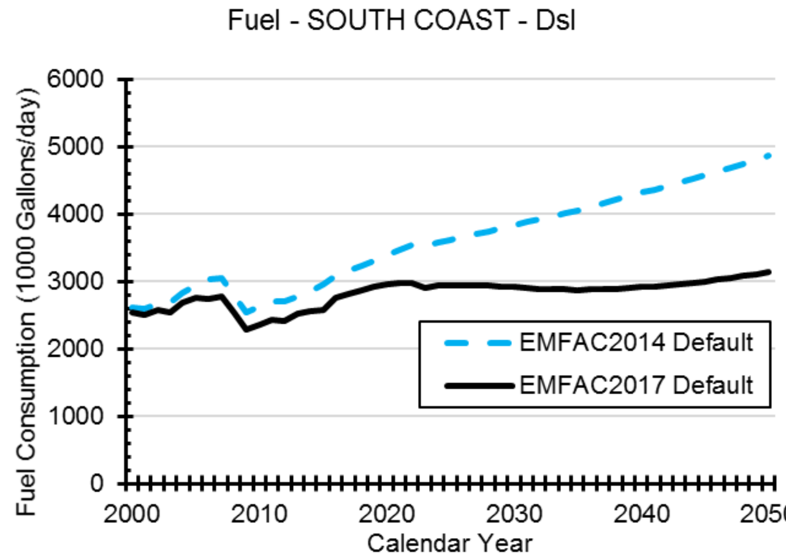
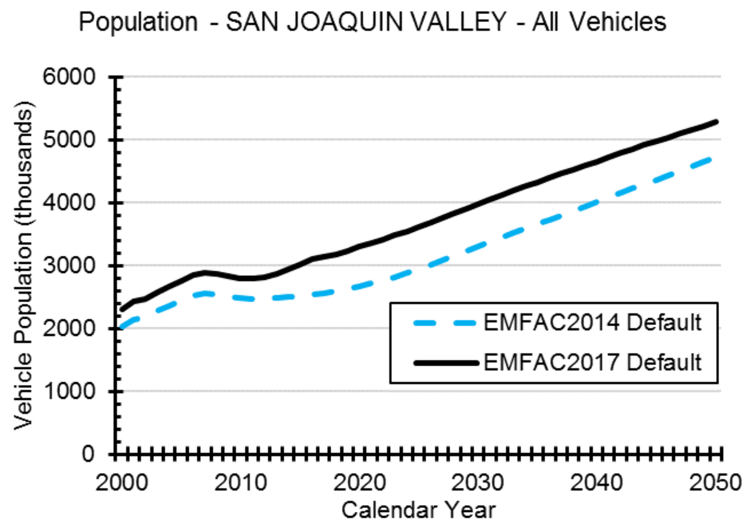
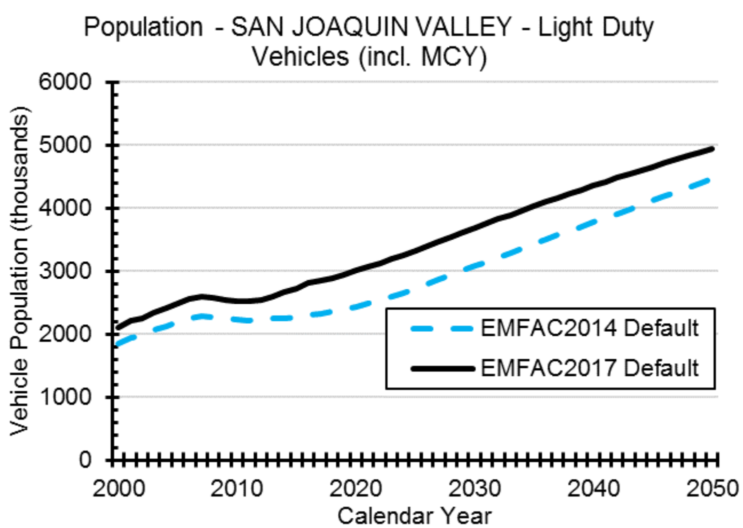
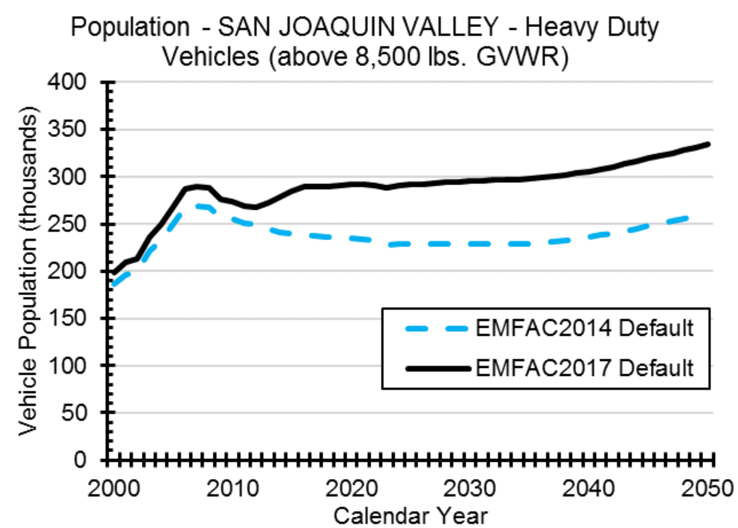


Figure 6.16-2. Comparison of Vehicle Activity and Emissions in San Joaquin Valley air basin between EMFAC2014 and EMFAC2017

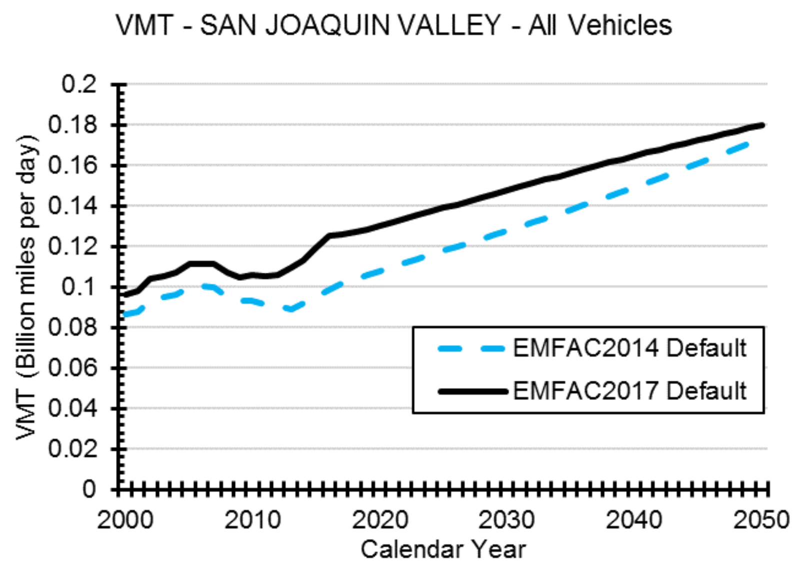
<u>Vehicle Population</u>

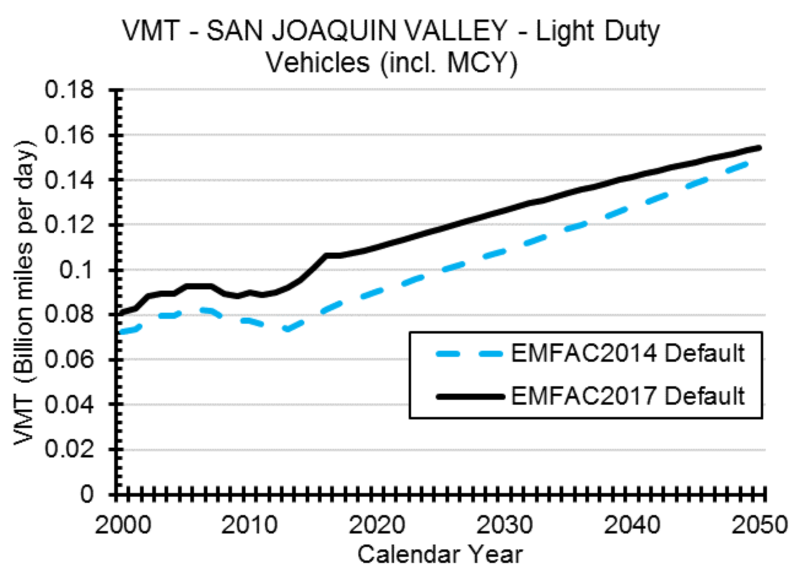


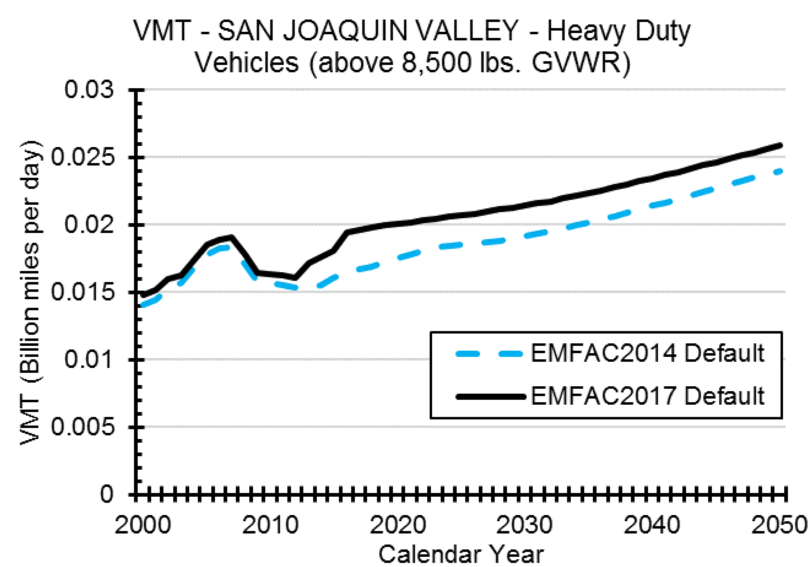




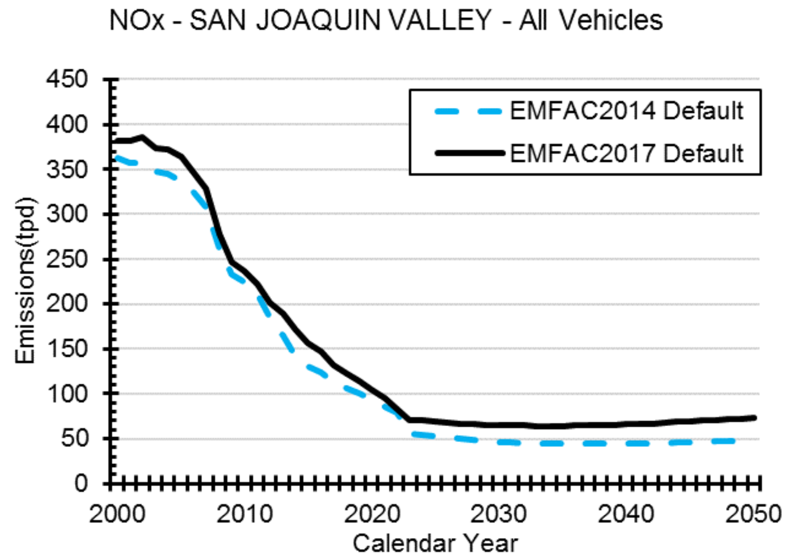
VMT

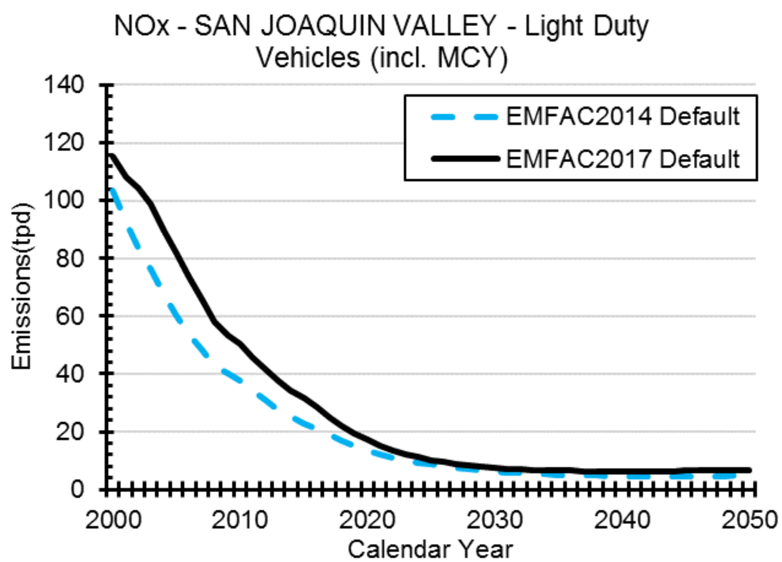

VMT - SAN JOAQUIN VALLEY - All Vehicles
VMT (Billion miles per day)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default

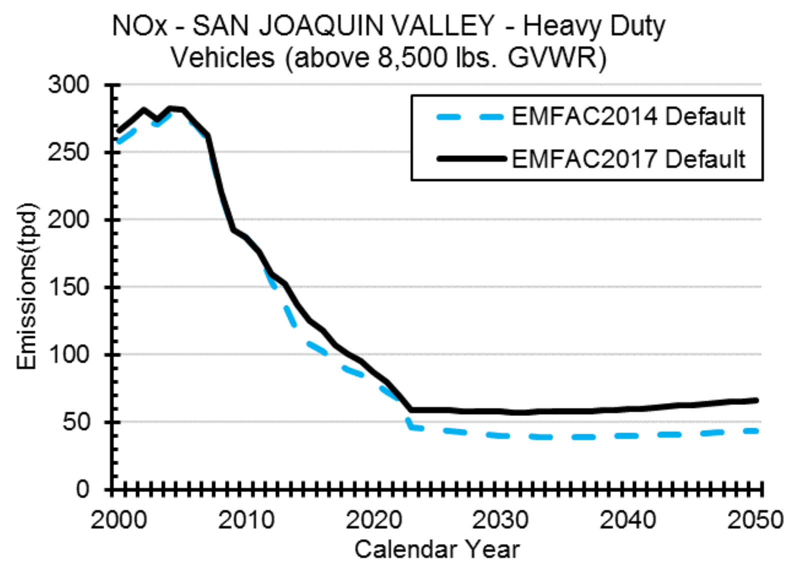

VMT - SAN JOAQUIN VALLEY - Light Duty Vehicles (incl. MCY)
VMT (Billion miles per day)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default


VMT - SAN JOAQUIN VALLEY - Heavy Duty Vehicles (above 8,500 lbs. GVWR)
VMT (Billion miles per day)
0.03
0.025
0.02
0.015
0.01
0.005
0
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default

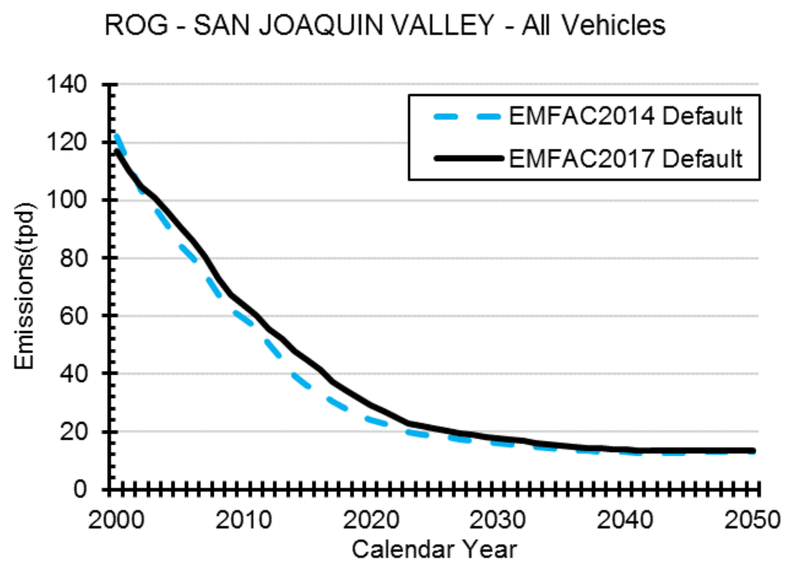
NOX


NOx - SAN JOAQUIN VALLEY - All Vehicles
450
400
350
300
250
200
150
100
50
0
Emissions(tpd)
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default

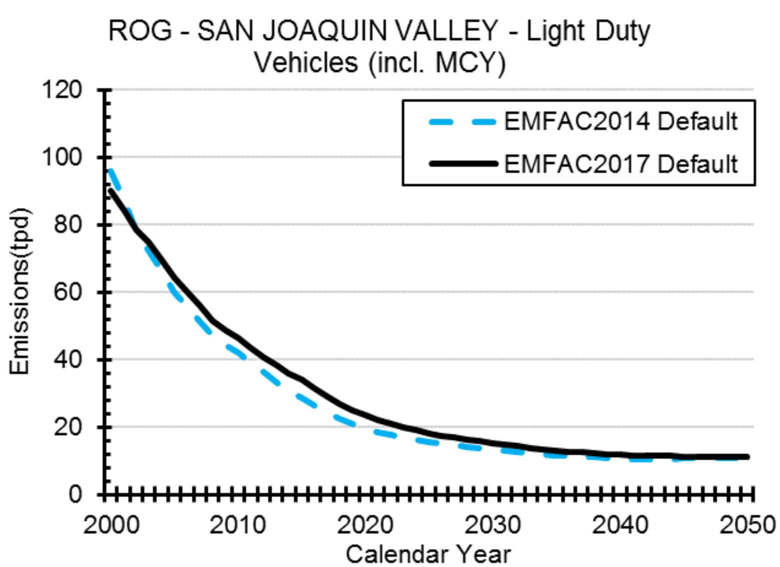

NOx - SAN JOAQUIN VALLEY - Light Duty Vehicles (incl. MCY)
140
120
100
80
60
40
20
0
Emissions(tpd)
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default


NOx - SAN JOAQUIN VALLEY - Heavy Duty Vehicles (above 8,500 lbs. GVWR)
300
250
200
150
100
50
0
Emissions(tpd)
2000
2010
2020
2030
2040
2050
Calendar Year
EMFAC2014 Default
EMFAC2017 Default

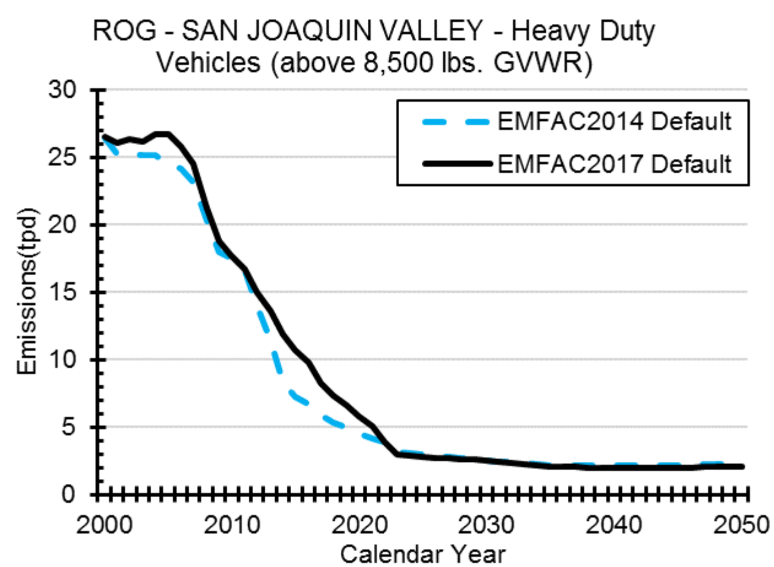
ROG



ROG - SAN JOAQUIN VALLEY - All Vehicles
EMFAC2014 Default
EMFAC2017 Default
Emissions(tpd)
0
20
40
60
80
100
120
140
2000
2010
2020
2030
2040
2050
Calendar Year

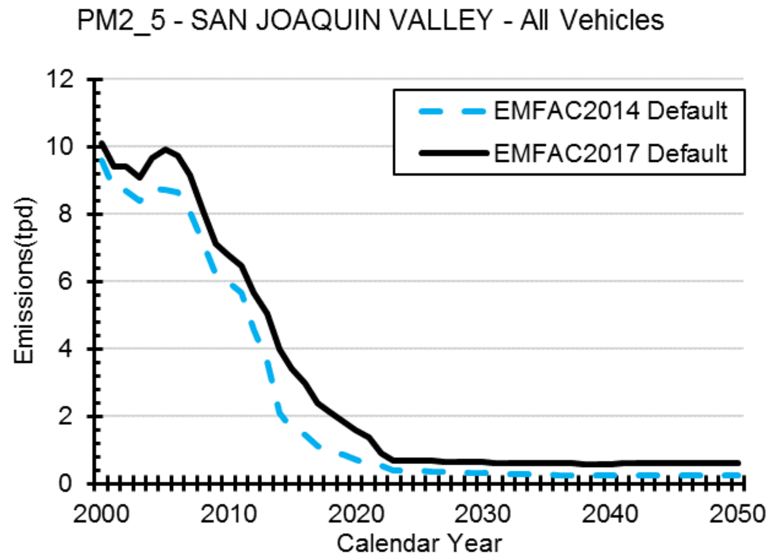


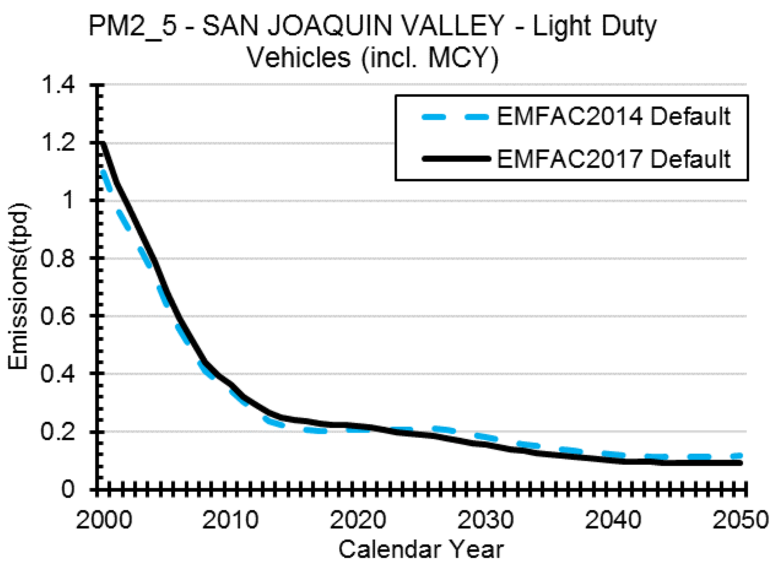
ROG - SAN JOAQUIN VALLEY - Light Duty Vehicles (incl. MCY)
EMFAC2014 Default
EMFAC2017 Default
Emissions(tpd)
0
20
40
60
80
100
120
2000
2010
2020
2030
2040
2050
Calendar Year

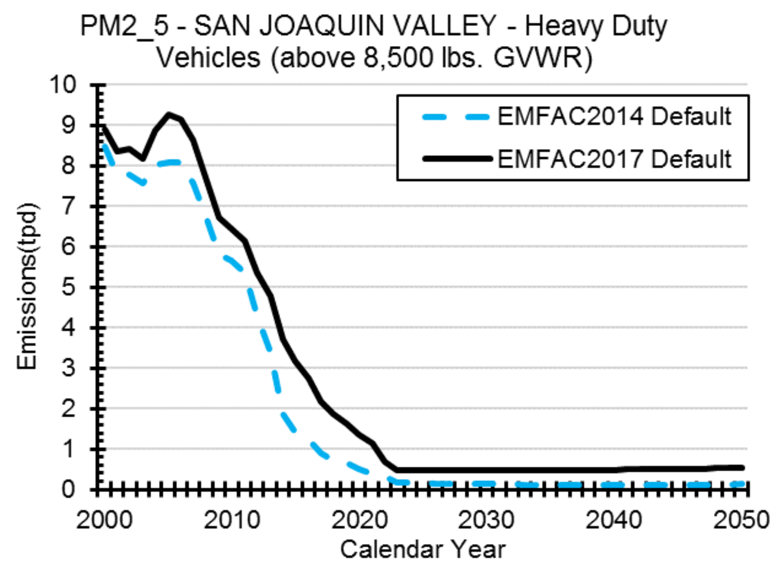


ROG - SAN JOAQUIN VALLEY - Heavy Duty Vehicles (above 8,500 lbs. GVWR)
EMFAC2014 Default
EMFAC2017 Default
Emissions(tpd)
0
5
10
15
20
25
30
2000
2010
2020
2030
2040
2050
Calendar Year

PM2.5 (Tailpipe)







Fuel Consumption